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YANG - A Data Modeling Language for the Network Configuration Protocol
(NETCONF)
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Abstract

YANG is a data modeling language used to model configuration and state data manipulated by the Network Configuration Protocol (NETCONF), NETCONF remote procedure calls, and NETCONF notifications. This document obsoletes RFC 6020.

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1. Introduction

YANG is a data modeling language used to model configuration and state data manipulated by the Network Configuration Protocol (NETCONF), NETCONF remote procedure calls, and NETCONF notifications. YANG is used to model the operations and content layers of NETCONF (see the NETCONF Configuration Protocol [RFC6241], Section 1.2).

This document describes the syntax and semantics of the YANG language, how the data model defined in a YANG module is represented in the Extensible Markup Language (XML), and how NETCONF operations are used to manipulate the data.

1.1. Summary of Changes from RFC 6020

This document defines version 1.1 of the YANG language. YANG version 1.1 is a maintenance release of the YANG language, addressing ambiguities and defects in the original specification [RFC6020].

- o Changed the YANG version from "1" to "1.1".
- o Made noncharacters illegal in the built-in type "string".
- o Defined the legal characters in YANG modules.
- o Made the "yang-version" statement mandatory.

- o Changed the rules for the interpretation of escaped characters in double quoted strings. This is a backwards incompatible change from YANG 1.0. A module that uses a character sequence that is now illegal must change the string to match the new rules. See Section 6.1.3 for details.
- o Extended the "if-feature" syntax to be a boolean expression over feature names.
- o Allow "if-feature" in "bit", "enum", and "identity".
- o Allow "if-feature" in "refine".
- o Made "when" and "if-feature" illegal on list keys, unless the parent is also conditional, and the condition matches the parent's condition.
- o Allow "choice" as a shorthand case statement (see Section 7.9).
- o Added a new substatement "modifier" to pattern (see Section 9.4.6).
- o Allow "must" in "input", "output", and "notification".
- o Added a set of new XPath functions in Section 10.
- o Clarified the XPath context's tree in Section 6.4.1.
- o Defined the string value of an identityref in XPath expressions (see Section 9.10).
- o Clarified what unprefixes names means in leafrefs in typedefs (see Section 9.9.2).
- o Allow identities to be derived from multiple base identities (see Section 7.17 and Section 9.10).
- o Allow enumerations to be subtyped (see Section 9.6).
- o Allow leaf-lists to have default values (see Section 7.7.2).
- o Use [RFC7405] syntax for case-sensitive strings in the grammar.
- o Changed the module advertisement mechanism (see Section 5.6.4).
- o Changed the scoping rules for definitions in submodules. A submodule can now reference all definitions in all submodules that belong to the same module, without using the "include" statement.

- o Added a new statement "action" that is used to define operations tied to data nodes.

2. Keywords

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14, [RFC2119].

3. Terminology

- o action: An operation defined for a node in the data tree.
- o anyxml: A data node that can contain an unknown chunk of XML data.
- o augment: Adds new schema nodes to a previously defined schema node.
- o base type: The type from which a derived type was derived, which may be either a built-in type or another derived type.
- o built-in type: A YANG data type defined in the YANG language, such as uint32 or string.
- o choice: A schema node where only one of a number of identified alternatives is valid.
- o configuration data: The set of writable data that is required to transform a system from its initial default state into its current state [RFC6241].
- o conformance: A measure of how accurately a device follows a data model.
- o container: An interior data node that exists in at most one instance in the data tree. A container has no value, but rather a set of child nodes.
- o data definition statement: A statement that defines new data nodes. One of container, leaf, leaf-list, list, choice, case, augment, uses, and anyxml.
- o data model: A data model describes how data is represented and accessed.
- o data node: A node in the schema tree that can be instantiated in a data tree. One of container, leaf, leaf-list, list, and anyxml.

- o data tree: The instantiated tree of configuration and state data on a device.
- o derived type: A type that is derived from a built-in type (such as uint32), or another derived type.
- o device deviation: A failure of the device to implement the module faithfully.
- o extension: An extension attaches non-YANG semantics to statements. The extension statement defines new statements to express these semantics.
- o feature: A mechanism for marking a portion of the model as optional. Definitions can be tagged with a feature name and are only valid on devices that support that feature.
- o grouping: A reusable set of schema nodes, which may be used locally in the module, in modules that include it, and by other modules that import from it. The grouping statement is not a data definition statement and, as such, does not define any nodes in the schema tree.
- o identifier: Used to identify different kinds of YANG items by name.
- o instance identifier: A mechanism for identifying a particular node in a data tree.
- o interior node: Nodes within a hierarchy that are not leaf nodes.
- o leaf: A data node that exists in at most one instance in the data tree. A leaf has a value but no child nodes.
- o leaf-list: Like the leaf node but defines a set of uniquely identifiable nodes rather than a single node. Each node has a value but no child nodes.
- o list: An interior data node that may exist in multiple instances in the data tree. A list has no value, but rather a set of child nodes.
- o module: A YANG module defines a hierarchy of nodes that can be used for NETCONF-based operations. With its definitions and the definitions it imports or includes from elsewhere, a module is self-contained and "compilable".
- o RPC: A Remote Procedure Call, as used within the NETCONF protocol.

- o RPC operation: A specific Remote Procedure Call, as used within the NETCONF protocol. It is also called a protocol operation.
- o schema node: A node in the schema tree. One of container, leaf, leaf-list, list, choice, case, rpc, input, output, notification, and anyxml.
- o schema node identifier: A mechanism for identifying a particular node in the schema tree.
- o schema tree: The definition hierarchy specified within a module.
- o state data: The additional data on a system that is not configuration data such as read-only status information and collected statistics [RFC6241].
- o submodule: A partial module definition that contributes derived types, groupings, data nodes, RPCs, and notifications to a module. A YANG module can be constructed from a number of submodules.
- o top-level data node: A data node where there is no other data node between it and a module or submodule statement.
- o uses: The "uses" statement is used to instantiate the set of schema nodes defined in a grouping statement. The instantiated nodes may be refined and augmented to tailor them to any specific needs.

3.1. Mandatory Nodes

A mandatory node is one of:

- o A leaf, choice, or anyxml node with a "mandatory" statement with the value "true".
- o A list or leaf-list node with a "min-elements" statement with a value greater than zero.
- o A container node without a "presence" statement, which has at least one mandatory node as a child.

4. YANG Overview

4.1. Functional Overview

YANG is a language used to model data for the NETCONF protocol. A YANG module defines a hierarchy of data that can be used for NETCONF-based operations, including configuration, state data, Remote

Procedure Calls (RPCs), and notifications. This allows a complete description of all data sent between a NETCONF client and server.

YANG models the hierarchical organization of data as a tree in which each node has a name, and either a value or a set of child nodes. YANG provides clear and concise descriptions of the nodes, as well as the interaction between those nodes.

YANG structures data models into modules and submodules. A module can import data from other external modules, and include data from submodules. The hierarchy can be augmented, allowing one module to add data nodes to the hierarchy defined in another module. This augmentation can be conditional, with new nodes appearing only if certain conditions are met.

YANG models can describe constraints to be enforced on the data, restricting the appearance or value of nodes based on the presence or value of other nodes in the hierarchy. These constraints are enforceable by either the client or the server, and valid content MUST abide by them.

YANG defines a set of built-in types, and has a type mechanism through which additional types may be defined. Derived types can restrict their base type's set of valid values using mechanisms like range or pattern restrictions that can be enforced by clients or servers. They can also define usage conventions for use of the derived type, such as a string-based type that contains a host name.

YANG permits the definition of reusable groupings of nodes. The instantiation of these groupings can refine or augment the nodes, allowing it to tailor the nodes to its particular needs. Derived types and groupings can be defined in one module or submodule and used in either that location or in another module or submodule that imports or includes it.

YANG data hierarchy constructs include defining lists where list entries are identified by keys that distinguish them from each other. Such lists may be defined as either sorted by user or automatically sorted by the system. For user-sorted lists, operations are defined for manipulating the order of the list entries.

YANG modules can be translated into an equivalent XML syntax called YANG Independent Notation (YIN) (Section 12), allowing applications using XML parsers and Extensible Stylesheet Language Transformations (XSLT) scripts to operate on the models. The conversion from YANG to YIN is lossless, so content in YIN can be round-tripped back into YANG.

YANG strikes a balance between high-level data modeling and low-level bits-on-the-wire encoding. The reader of a YANG module can see the high-level view of the data model while understanding how the data will be encoded in NETCONF operations.

YANG is an extensible language, allowing extension statements to be defined by standards bodies, vendors, and individuals. The statement syntax allows these extensions to coexist with standard YANG statements in a natural way, while extensions in a YANG module stand out sufficiently for the reader to notice them.

YANG resists the tendency to solve all possible problems, limiting the problem space to allow expression of NETCONF data models, not arbitrary XML documents or arbitrary data models. The data models described by YANG are designed to be easily operated upon by NETCONF operations.

To the extent possible, YANG maintains compatibility with Simple Network Management Protocol's (SNMP's) SMIV2 (Structure of Management Information version 2 [RFC2578], [RFC2579]). SMIV2-based MIB modules can be automatically translated into YANG modules for read-only access. However, YANG is not concerned with reverse translation from YANG to SMIV2.

Like NETCONF, YANG targets smooth integration with the device's native management infrastructure. This allows implementations to leverage their existing access control mechanisms to protect or expose elements of the data model.

4.2. Language Overview

This section introduces some important constructs used in YANG that will aid in the understanding of the language specifics in later sections. This progressive approach handles the inter-related nature of YANG concepts and statements. A detailed description of YANG statements and syntax begins in Section 7.

4.2.1. Modules and Submodules

A module contains three types of statements: module-header statements, revision statements, and definition statements. The module header statements describe the module and give information about the module itself, the revision statements give information about the history of the module, and the definition statements are the body of the module where the data model is defined.

A NETCONF server may implement a number of modules, allowing multiple views of the same data, or multiple views of disjoint subsections of

the device's data. Alternatively, the server may implement only one module that defines all available data.

A module may be divided into submodules, based on the needs of the module owner. The external view remains that of a single module, regardless of the presence or size of its submodules.

The "import" statement allows a module or submodule to reference material defined in other modules.

The "include" statement is used by a module to incorporate the contents of its submodules into the module.

4.2.2. Data Modeling Basics

YANG defines four types of nodes for data modeling. In each of the following subsections, the example shows the YANG syntax as well as a corresponding NETCONF XML representation.

4.2.2.1. Leaf Nodes

A leaf node contains simple data like an integer or a string. It has exactly one value of a particular type and no child nodes.

YANG Example:

```
leaf host-name {  
    type string;  
    description "Hostname for this system";  
}
```

NETCONF XML Example:

```
<host-name>my.example.com</host-name>
```

The "leaf" statement is covered in Section 7.6.

4.2.2.2. Leaf-List Nodes

A leaf-list defines a sequence of values of a particular type.

YANG Example:

```
leaf-list domain-search {  
    type string;  
    description "List of domain names to search";  
}
```

NETCONF XML Example:

```
<domain-search>high.example.com</domain-search>
<domain-search>low.example.com</domain-search>
<domain-search>everywhere.example.com</domain-search>
```

The "leaf-list" statement is covered in Section 7.7.

4.2.2.3. Container Nodes

A container node is used to group related nodes in a subtree. A container has only child nodes and no value. A container may contain any number of child nodes of any type (including leafs, lists, containers, and leaf-lists).

YANG Example:

```
container system {
  container login {
    leaf message {
      type string;
      description
        "Message given at start of login session";
    }
  }
}
```

NETCONF XML Example:

```
<system>
  <login>
    <message>Good morning</message>
  </login>
</system>
```

The "container" statement is covered in Section 7.5.

4.2.2.4. List Nodes

A list defines a sequence of list entries. Each entry is like a structure or a record instance, and is uniquely identified by the values of its key leafs. A list can define multiple key leafs and may contain any number of child nodes of any type (including leafs, lists, containers etc.).

YANG Example:


```
list user {  
    key "name";  
    leaf name {  
        type string;  
    }  
    leaf full-name {  
        type string;  
    }  
    leaf class {  
        type string;  
    }  
}
```

NETCONF XML Example:

```
<user>  
  <name>glocks</name>  
  <full-name>Goldie Locks</full-name>  
  <class>intruder</class>  
</user>  
<user>  
  <name>snowey</name>  
  <full-name>Snow White</full-name>  
  <class>free-loader</class>  
</user>  
<user>  
  <name>rzell</name>  
  <full-name>Rapun Zell</full-name>  
  <class>tower</class>  
</user>
```

The "list" statement is covered in Section 7.8.

4.2.2.5. Example Module

These statements are combined to define the module:

```
// Contents of "acme-system.yang"
module acme-system {
  yang-version 1.1;
  namespace "http://acme.example.com/system";
  prefix "acme";

  organization "ACME Inc.";
  contact "joe@acme.example.com";
  description
    "The module for entities implementing the ACME system.";

  revision 2007-06-09 {
    description "Initial revision.";
  }

  container system {
    leaf host-name {
      type string;
      description "Hostname for this system";
    }

    leaf-list domain-search {
      type string;
      description "List of domain names to search";
    }

    container login {
      leaf message {
        type string;
        description
          "Message given at start of login session";
      }

      list user {
        key "name";
        leaf name {
          type string;
        }
        leaf full-name {
          type string;
        }
        leaf class {
          type string;
        }
      }
    }
  }
}
```

4.2.3. State Data

YANG can model state data, as well as configuration data, based on the "config" statement. When a node is tagged with "config false", its subhierarchy is flagged as state data, to be reported using NETCONF's <get> operation, not the <get-config> operation. Parent containers, lists, and key leafs are reported also, giving the context for the state data.

In this example, two leafs are defined for each interface, a configured speed and an observed speed. The observed speed is not configuration, so it can be returned with NETCONF <get> operations, but not with <get-config> operations. The observed speed is not configuration data, and it cannot be manipulated using <edit-config>.

```
list interface {
  key "name";

  leaf name {
    type string;
  }
  leaf speed {
    type enumeration {
      enum 10m;
      enum 100m;
      enum auto;
    }
  }
  leaf observed-speed {
    type uint32;
    config false;
  }
}
```

4.2.4. Built-In Types

YANG has a set of built-in types, similar to those of many programming languages, but with some differences due to special requirements from the management domain. The following table summarizes the built-in types discussed in Section 9:

| Name | Description |
|---------------------|-------------------------------------|
| binary | Any binary data |
| bits | A set of bits or flags |
| boolean | "true" or "false" |
| decimal64 | 64-bit signed decimal number |
| empty | A leaf that does not have any value |
| enumeration | Enumerated strings |
| identityref | A reference to an abstract identity |
| instance-identifier | References a data tree node |
| int8 | 8-bit signed integer |
| int16 | 16-bit signed integer |
| int32 | 32-bit signed integer |
| int64 | 64-bit signed integer |
| leafref | A reference to a leaf instance |
| string | Human-readable string |
| uint8 | 8-bit unsigned integer |
| uint16 | 16-bit unsigned integer |
| uint32 | 32-bit unsigned integer |
| uint64 | 64-bit unsigned integer |
| union | Choice of member types |

The "type" statement is covered in Section 7.4.

4.2.5. Derived Types (typedef)

YANG can define derived types from base types using the "typedef" statement. A base type can be either a built-in type or a derived type, allowing a hierarchy of derived types.

A derived type can be used as the argument for the "type" statement.

YANG Example:

```
typedef percent {
    type uint8 {
        range "0 .. 100";
    }
    description "Percentage";
}

leaf completed {
    type percent;
}
```

NETCONF XML Example:

<completed>20</completed>

The "typedef" statement is covered in Section 7.3.

4.2.6. Reusable Node Groups (grouping)

Groups of nodes can be assembled into reusable collections using the "grouping" statement. A grouping defines a set of nodes that are instantiated with the "uses" statement:

```
grouping target {
  leaf address {
    type inet:ip-address;
    description "Target IP address";
  }
  leaf port {
    type inet:port-number;
    description "Target port number";
  }
}

container peer {
  container destination {
    uses target;
  }
}
```

NETCONF XML Example:

```
<peer>
  <destination>
    <address>192.0.2.1</address>
    <port>830</port>
  </destination>
</peer>
```

The grouping can be refined as it is used, allowing certain statements to be overridden. In this example, the description is refined:

```
    container connection {
      container source {
        uses target {
          refine "address" {
            description "Source IP address";
          }
          refine "port" {
            description "Source port number";
          }
        }
      }
      container destination {
        uses target {
          refine "address" {
            description "Destination IP address";
          }
          refine "port" {
            description "Destination port number";
          }
        }
      }
    }
  }
```

The "grouping" statement is covered in Section 7.11.

4.2.7. Choices

YANG allows the data model to segregate incompatible nodes into distinct choices using the "choice" and "case" statements. The "choice" statement contains a set of "case" statements that define sets of schema nodes that cannot appear together. Each "case" may contain multiple nodes, but each node may appear in only one "case" under a "choice".

When a node from one case is created in the data tree, all nodes from all other cases are implicitly deleted. The device handles the enforcement of the constraint, preventing incompatibilities from existing in the configuration.

The choice and case nodes appear only in the schema tree, not in the data tree or NETCONF messages. The additional levels of hierarchy are not needed beyond the conceptual schema.

YANG Example:

```
container food {
  choice snack {
    case sports-arena {
      leaf pretzel {
        type empty;
      }
      leaf beer {
        type empty;
      }
    }
    case late-night {
      leaf chocolate {
        type enumeration {
          enum dark;
          enum milk;
          enum first-available;
        }
      }
    }
  }
}
```

NETCONF XML Example:

```
<food>
  <pretzel/>
  <beer/>
</food>
```

The "choice" statement is covered in Section 7.9.

4.2.8. Extending Data Models (augment)

YANG allows a module to insert additional nodes into data models, including both the current module (and its submodules) or an external module. This is useful for example for vendors to add vendor-specific parameters to standard data models in an interoperable way.

The "augment" statement defines the location in the data model hierarchy where new nodes are inserted, and the "when" statement defines the conditions when the new nodes are valid.

YANG Example:

```
augment /system/login/user {
  when "class != 'wheel'";
  leaf uid {
    type uint16 {
      range "1000 .. 30000";
    }
  }
}
```

This example defines a "uid" node that only is valid when the user's "class" is not "wheel".

If a module augments another module, the XML representation of the data will reflect the prefix of the augmenting module. For example, if the above augmentation were in a module with prefix "other", the XML would look like:

NETCONF XML Example:

```
<user>
  <name>alicew</name>
  <full-name>Alice N. Wonderland</full-name>
  <class>drop-out</class>
  <other:uid>1024</other:uid>
</user>
```

The "augment" statement is covered in Section 7.16.

4.2.9. Operation Definitions

YANG allows the definition of operations. The operations' names, input parameters, and output parameters are modeled using YANG data definition statements. Operations on the top-level in a module are defined with the "rpc" statement. Operations can also be tied to a node in the data hierarchy. Such operations are defined with the "action" statement.

YANG Example:


```
rpc activate-software-image {  
  input {  
    leaf image-name {  
      type string;  
    }  
  }  
  output {  
    leaf status {  
      type string;  
    }  
  }  
}
```

NETCONF XML Example:

```
<rpc message-id="101"  
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  
  <activate-software-image xmlns="http://acme.example.com/system">  
    <image-name>acmefw-2.3</image-name>  
  </activate-software-image>  
</rpc>  
  
<rpc-reply message-id="101"  
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  
  <status xmlns="http://acme.example.com/system">  
    The image acmefw-2.3 is being installed.  
  </status>  
</rpc-reply>
```

The "rpc" statement is covered in Section 7.13, and the "action" statement in Section 7.14.

4.2.10. Notification Definitions

YANG allows the definition of notifications suitable for NETCONF. YANG data definition statements are used to model the content of the notification.

YANG Example:

```
notification link-failure {
  description "A link failure has been detected";
  leaf if-name {
    type leafref {
      path "/interface/name";
    }
  }
  leaf if-admin-status {
    type admin-status;
  }
  leaf if-oper-status {
    type oper-status;
  }
}
```

NETCONF XML Example:

```
<notification
  xmlns="urn:ietf:params:netconf:capability:notification:1.0">
  <eventTime>2007-09-01T10:00:00Z</eventTime>
  <link-failure xmlns="http://acme.example.com/system">
    <if-name>so-1/2/3.0</if-name>
    <if-admin-status>up</if-admin-status>
    <if-oper-status>down</if-oper-status>
  </link-failure>
</notification>
```

The "notification" statement is covered in Section 7.15.

5. Language Concepts

5.1. Modules and Submodules

The module is the base unit of definition in YANG. A module defines a single data model. A module can define a complete, cohesive model, or augment an existing data model with additional nodes.

Submodules are partial modules that contribute definitions to a module. A module may include any number of submodules, but each submodule may belong to only one module.

The names of all standard modules and submodules MUST be unique. Developers of enterprise modules are RECOMMENDED to choose names for their modules that will have a low probability of colliding with standard or other enterprise modules, e.g., by using the enterprise or organization name as a prefix for the module name.

A module uses the "include" statement to include all its submodules, and the "import" statement to reference external modules. Similarly, a submodule uses the "import" statement to reference other modules.

For backwards compatibility with YANG version 1, a submodule is allowed to use the "include" statement to reference other submodules within its module, but this is not necessary in YANG version 1.1. A submodule can reference any definition in the module it belongs to and in all submodules included by the module.

A module or submodule MUST NOT include submodules from other modules, and a submodule MUST NOT import its own module.

The import and include statements are used to make definitions available from other modules:

- o For a module or submodule to reference definitions in an external module, the external module MUST be imported.
- o A module MUST include all its submodules.
- o A module or submodule belonging to that module can reference definitions in the module and all submodules included by the module.

There MUST NOT be any circular chains of imports or includes. For example, if module "a" imports module "b", "b" cannot import "a".

When a definition in an external module is referenced, a locally defined prefix MUST be used, followed by ":", and then the external identifier. References to definitions in the local module MAY use the prefix notation. Since built-in data types do not belong to any module and have no prefix, references to built-in data types (e.g., int32) cannot use the prefix notation. The syntax for a reference to a definition is formally defined by the rule "identifier-ref" in Section 13.

5.1.1. Import and Include by Revision

Published modules evolve independently over time. In order to allow for this evolution, modules need to be imported using specific revisions. When a module is written, it uses the current revisions of other modules, based on what is available at the time. As future revisions of the imported modules are published, the importing module is unaffected and its contents are unchanged. When the author of the module is prepared to move to the most recently published revision of an imported module, the module is republished with an updated "import" statement. By republishing with the new revision, the

authors explicitly indicate their acceptance of any changes in the imported module.

For submodules, the issue is related but simpler. A module or submodule that includes submodules needs to specify the revision of the included submodules. If a submodule changes, any module or submodule that includes it needs to be updated.

For example, module "b" imports module "a".

```
module a {
  yang-version 1.1;
  namespace "http://example.com/a";
  prefix "a";

  revision 2008-01-01 { ... }
  grouping a {
    leaf eh { .... }
  }
}

module b {
  yang-version 1.1;
  namespace "http://example.com/b";
  prefix "b";

  import a {
    prefix p;
    revision-date 2008-01-01;
  }

  container bee {
    uses p:a;
  }
}
```

When the author of "a" publishes a new revision, the changes may not be acceptable to the author of "b". If the new revision is acceptable, the author of "b" can republish with an updated revision in the "import" statement.

5.1.2. Module Hierarchies

YANG allows modeling of data in multiple hierarchies, where data may have more than one top-level node. Models that have multiple top-level nodes are sometimes convenient, and are supported by YANG.

NETCONF is capable of carrying any XML content as the payload in the <config> and <data> elements. The top-level nodes of YANG modules are encoded as child elements, in any order, within these elements. This encapsulation guarantees that the corresponding NETCONF messages are always well-formed XML documents.

For example:

```
module my-config {  
  yang-version 1.1;  
  namespace "http://example.com/schema/config";  
  prefix "co";  
  
  container system { ... }  
  container routing { ... }  
}
```

could be encoded in NETCONF as:

```
<rpc message-id="101"  
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"  
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0">  
  <edit-config>  
    <target>  
      <running/>  
    </target>  
    <config>  
      <system xmlns="http://example.com/schema/config">  
        <!-- system data here -->  
      </system>  
      <routing xmlns="http://example.com/schema/config">  
        <!-- routing data here -->  
      </routing>  
    </config>  
  </edit-config>  
</rpc>
```

5.2. File Layout

YANG modules and submodules are typically stored in files, one module or submodule per file. The name of the file SHOULD be of the form:

```
module-or-submodule-name ['@' revision-date] ( '.yang' / '.yin' )
```

YANG compilers can find imported modules and included submodules via this convention. While the YANG language defines modules, tools may compile submodules independently for performance and manageability reasons. Errors and warnings that cannot be detected during

submodule compilation may be delayed until the submodules are linked into a cohesive module.

5.3. XML Namespaces

All YANG definitions are specified within a module that is bound to a particular XML namespace [XML-NAMES], which is a globally unique URI [RFC3986]. A NETCONF client or server uses the namespace during XML encoding of data.

Namespaces for modules published in RFC streams [RFC4844] MUST be assigned by IANA, see Section 15.

Namespaces for private modules are assigned by the organization owning the module without a central registry. Namespace URIs MUST be chosen so they cannot collide with standard or other enterprise namespaces, for example by using the enterprise or organization name in the namespace.

The "namespace" statement is covered in Section 7.1.3.

5.3.1. YANG XML Namespace

YANG defines an XML namespace for NETCONF <edit-config> operations, <error-info> content, and the <action> element. The name of this namespace is "urn:ietf:params:xml:ns:yang:1".

5.4. Resolving Grouping, Type, and Identity Names

Grouping, type, and identity names are resolved in the context in which they are defined, rather than the context in which they are used. Users of groupings, typedefs, and identities are not required to import modules or include submodules to satisfy all references made by the original definition. This behaves like static scoping in a conventional programming language.

For example, if a module defines a grouping in which a type is referenced, when the grouping is used in a second module, the type is resolved in the context of the original module, not the second module. There is no worry over conflicts if both modules define the type, since there is no ambiguity.

5.5. Nested Typedefs and Groupings

Typedefs and groupings may appear nested under many YANG statements, allowing these to be lexically scoped by the hierarchy under which they appear. This allows types and groupings to be defined near

where they are used, rather than placing them at the top level of the hierarchy. The close proximity increases readability.

Scoping also allows types to be defined without concern for naming conflicts between types in different submodules. Type names can be specified without adding leading strings designed to prevent name collisions within large modules.

Finally, scoping allows the module author to keep types and groupings private to their module or submodule, preventing their reuse. Since only top-level types and groupings (i.e., those appearing as substatements to a module or submodule statement) can be used outside the module or submodule, the developer has more control over what pieces of their module are presented to the outside world, supporting the need to hide internal information and maintaining a boundary between what is shared with the outside world and what is kept private.

Scoped definitions **MUST NOT** shadow definitions at a higher scope. A type or grouping cannot be defined if a higher level in the schema hierarchy has a definition with a matching identifier.

A reference to an unprefixed type or grouping, or one which uses the prefix of the current module, is resolved by locating the closest matching "typedef" or "grouping" statement among the immediate substatements of each ancestor statement.

5.6. Conformance

Conformance is a measure of how accurately a device follows the model. Generally speaking, devices are responsible for implementing the model faithfully, allowing applications to treat devices which implement the model identically. Deviations from the model can reduce the utility of the model and increase fragility of applications that use it.

YANG modelers have three mechanisms for conformance:

- o the basic behavior of the model
- o optional features that are part of the model
- o deviations from the model

We will consider each of these in sequence.

5.6.1. Basic Behavior

The model defines a contract between the NETCONF client and server, which allows both parties to have faith the other knows the syntax and semantics behind the modeled data. The strength of YANG lies in the strength of this contract.

5.6.2. Optional Features

In many models, the modeler will allow sections of the model to be conditional. The device controls whether these conditional portions of the model are supported or valid for that particular device.

For example, a syslog data model may choose to include the ability to save logs locally, but the modeler will realize that this is only possible if the device has local storage. If there is no local storage, an application should not tell the device to save logs.

YANG supports this conditional mechanism using a construct called "feature". Features give the modeler a mechanism for making portions of the module conditional in a manner that is controlled by the device. The model can express constructs that are not universally present in all devices. These features are included in the model definition, allowing a consistent view and allowing applications to learn which features are supported and tailor their behavior to the device.

A module may declare any number of features, identified by simple strings, and may make portions of the module optional based on those features. If the device supports a feature, then the corresponding portions of the module are valid for that device. If the device doesn't support the feature, those parts of the module are not valid, and applications should behave accordingly.

Features are defined using the "feature" statement. Definitions in the module that are conditional to the feature are noted by the "if-feature" statement.

Further details are available in Section 7.19.1.

5.6.3. Deviations

In an ideal world, all devices would be required to implement the model exactly as defined, and deviations from the model would not be allowed. But in the real world, devices are often not able or designed to implement the model as written. For YANG-based automation to deal with these device deviations, a mechanism must

exist for devices to inform applications of the specifics of such deviations.

For example, a BGP module may allow any number of BGP peers, but a particular device may only support 16 BGP peers. Any application configuring the 17th peer will receive an error. While an error may suffice to let the application know it cannot add another peer, it would be far better if the application had prior knowledge of this limitation and could prevent the user from starting down the path that could not succeed.

Device deviations are declared using the "deviation" statement, which takes as its argument a string that identifies a node in the schema tree. The contents of the statement details the manner in which the device implementation deviates from the contract as defined in the module.

Further details are available in Section 7.19.3.

5.6.4. Announcing Conformance Information in the <hello> Message

This document defines the following mechanism for announcing conformance information. Other mechanisms may be defined by future specifications.

A NETCONF server announces the modules it implements by implementing the YANG module "ietf-yang-library" defined in [I-D.ietf-netconf-yang-library]. The server also advertises the following capability in the <hello> message (line-breaks and whitespaces are used for formatting reasons only):

```
urn:ietf:params:netconf:capability:yang-library:1.0?
  module-set-id=<id>
```

The parameter "module-set-id" has the same value as the leaf "/modules/module-set-id" from "ietf-yang-library". This parameter MUST be present.

With this mechanism, a client can cache the supported modules for a server, and only update the cache if the "module-set-id" value in the <hello> message changes.

5.7. Data Store Modification

Data models may allow the server to alter the configuration data store in ways not explicitly directed via NETCONF protocol messages. For example, a data model may define leafs that are assigned system-generated values when the client does not provide one. A formal

mechanism for specifying the circumstances where these changes are allowed is out of scope for this specification.

6. YANG Syntax

The YANG syntax is similar to that of SMIng [RFC3780] and programming languages like C and C++. This C-like syntax was chosen specifically for its readability, since YANG values the time and effort of the readers of models above those of modules writers and YANG tool-chain developers. This section introduces the YANG syntax.

YANG modules use the UTF-8 [RFC3629] character encoding.

Legal characters in YANG modules are the Unicode and ISO/IEC 10646 [ISO.10646] characters, including tab, carriage return, and line feed but excluding the other C0 control characters, the surrogate blocks, and the noncharacters. The character syntax is formally defined by the rule "yang-char" in Section 13.

6.1. Lexical Tokenization

YANG modules are parsed as a series of tokens. This section details the rules for recognizing tokens from an input stream. YANG tokenization rules are both simple and powerful. The simplicity is driven by a need to keep the parsers easy to implement, while the power is driven by the fact that modelers need to express their models in readable formats.

6.1.1. Comments

Comments are C++ style. A single line comment starts with `"/"` and ends at the end of the line. A block comment is enclosed within `"/"` and `"/"`.

6.1.2. Tokens

A token in YANG is either a keyword, a string, a semicolon (`;`), or braces (`{` or `}`). A string can be quoted or unquoted. A keyword is either one of the YANG keywords defined in this document, or a prefix identifier, followed by `:`, followed by a language extension keyword. Keywords are case sensitive. See Section 6.2 for a formal definition of identifiers.

6.1.3. Quoting

If a string contains any space or tab characters, a semicolon (`;`), braces (`{` or `}`), or comment sequences (`"/"`, `"/"`, or `"/"`), then it MUST be enclosed within double or single quotes.

If the double-quoted string contains a line break followed by space or tab characters that are used to indent the text according to the layout in the YANG file, this leading whitespace is stripped from the string, up to and including the column of the double quote character, or to the first non-whitespace character, whichever occurs first. In this process, a tab character is treated as 8 space characters.

If the double-quoted string contains space or tab characters before a line break, this trailing whitespace is stripped from the string.

A single-quoted string (enclosed within ' ') preserves each character within the quotes. A single quote character cannot occur in a single-quoted string, even when preceded by a backslash.

Within a double-quoted string (enclosed within " "), a backslash character introduces a special character, which depends on the character that immediately follows the backslash:

| | |
|-----------------|--------------------|
| <code>\n</code> | new line |
| <code>\t</code> | a tab character |
| <code>\"</code> | a double quote |
| <code>\\</code> | a single backslash |

It is an error if any other character follows the backslash character.

If a quoted string is followed by a plus character ("+"), followed by another quoted string, the two strings are concatenated into one string, allowing multiple concatenations to build one string. Whitespace trimming and substitution of backslash-escaped characters in double-quoted strings is done before concatenation.

6.1.3.1. Quoting Examples

The following strings are equivalent:

```
hello
"hello"
'hello'
"hel" + "lo"
'hel' + "lo"
```

The following examples show some special strings:

```
"\"" - string containing a double quote
'""' - string containing a double quote
"\n" - string containing a new line character
'\n' - string containing a backslash followed
      by the character n
```

The following examples show some illegal strings:

```
'''' - a single-quoted string cannot contain single quotes
"""" - a double quote must be escaped in a double-quoted string
```

The following strings are equivalent:

```
"first line
  second line"

"first line\n" + "  second line"
```

6.2. Identifiers

Identifiers are used to identify different kinds of YANG items by name. Each identifier starts with an uppercase or lowercase ASCII letter or an underscore character, followed by zero or more ASCII letters, digits, underscore characters, hyphens, and dots. Implementations **MUST** support identifiers up to 64 characters in length. Identifiers are case sensitive. The identifier syntax is formally defined by the rule "identifier" in Section 13. Identifiers can be specified as quoted or unquoted strings.

6.2.1. Identifiers and Their Namespaces

Each identifier is valid in a namespace that depends on the type of the YANG item being defined. All identifiers defined in a namespace **MUST** be unique.

- o All module and submodule names share the same global module identifier namespace.
- o All extension names defined in a module and its submodules share the same extension identifier namespace.
- o All feature names defined in a module and its submodules share the same feature identifier namespace.
- o All identity names defined in a module and its submodules share the same identity identifier namespace.

- o All derived type names defined within a parent node or at the top level of the module or its submodules share the same type identifier namespace. This namespace is scoped to all descendant nodes of the parent node or module. This means that any descendent node may use that typedef, and it MUST NOT define a typedef with the same name.
- o All grouping names defined within a parent node or at the top level of the module or its submodules share the same grouping identifier namespace. This namespace is scoped to all descendant nodes of the parent node or module. This means that any descendent node may use that grouping, and it MUST NOT define a grouping with the same name.
- o All leafs, leaf-lists, lists, containers, choices, rpcs, notifications, and anyxmls defined (directly or through a uses statement) within a parent node or at the top level of the module or its submodules share the same identifier namespace. This namespace is scoped to the parent node or module, unless the parent node is a case node. In that case, the namespace is scoped to the closest ancestor node that is not a case or choice node.
- o All cases within a choice share the same case identifier namespace. This namespace is scoped to the parent choice node.

Forward references are allowed in YANG.

6.3. Statements

A YANG module contains a sequence of statements. Each statement starts with a keyword, followed by zero or one argument, followed either by a semicolon (";") or a block of substatements enclosed within braces ("{" "}"):

```
statement = keyword [argument] (";" / "{" *statement "}")
```

The argument is a string, as defined in Section 6.1.2.

6.3.1. Language Extensions

A module can introduce YANG extensions by using the "extension" keyword (see Section 7.18). The extensions can be imported by other modules with the "import" statement (see Section 7.1.5). When an imported extension is used, the extension's keyword MUST be qualified using the prefix with which the extension's module was imported. If an extension is used in the module where it is defined, the extension's keyword MUST be qualified with the module's prefix.

If a YANG compiler does not support a particular extension, which appears in a YANG module as an unknown-statement (see Section 13), the entire unknown-statement MAY be ignored by the compiler.

6.4. XPath Evaluations

YANG relies on XML Path Language (XPath) 1.0 [XPATH] as a notation for specifying many inter-node references and dependencies. NETCONF clients and servers are not required to implement an XPath interpreter, but MUST ensure that the requirements encoded in the data model are enforced. The manner of enforcement is an implementation decision. The XPath expressions MUST be syntactically correct, and all prefixes used MUST be present in the XPath context (see Section 6.4.1). An implementation may choose to implement them by hand, rather than using the XPath expression directly.

The data model used in the XPath expressions is the same as that used in XPath 1.0 [XPATH], with the same extension for root node children as used by XSLT 1.0 [XSLT] (Section 3.1). Specifically, it means that the root node may have any number of element nodes as its children.

Numbers in XPath 1.0 are IEEE 754 double-precision floating-point values, see Section 3.5 in [XPATH]. This means that some values of int64, uint64 and decimal64 types (see Section 9.2 and Section 9.3) cannot be exactly represented in XPath expressions. Therefore, due caution should be exercised when using nodes with 64-bit numeric values in XPath expressions. In particular, numerical comparisons involving equality may yield unexpected results.

For example, consider the following definition:

```
leaf lxiv {  
    type decimal64 {  
        fraction-digits 18;  
    }  
    must ". <= 10";  
}
```

An instance of the "lxiv" leaf having the value of 10.0000000000000001 will then successfully pass validation.

6.4.1. XPath Context

All YANG XPath expressions share the following XPath context definition:

- o The set of namespace declarations is the set of all "import" statements' prefix and namespace pairs in the module where the XPath expression is specified, and the "prefix" statement's prefix for the "namespace" statement's URI.
- o Names without a namespace prefix belong to the same namespace as the identifier of the current node. Inside a grouping, that namespace is affected by where the grouping is used (see Section 7.12). Inside a typedef, that namespace is affected by where the typedef is referenced. If a typedef is defined and referenced within a grouping, the namespace is affected by where the grouping is used (see Section 7.12).
- o The function library is the core function library defined in [XPATH], and the functions defined in Section 10.
- o The set of variable bindings is empty.

The mechanism for handling unprefixed names is adopted from XPath 2.0 [XPATH2.0], and helps simplify XPath expressions in YANG. No ambiguity may ever arise because YANG node identifiers are always qualified names with a non-null namespace URI.

The accessible tree depends on where the statement with the XPath expression is defined:

- o If the XPath expression is defined in substatement to a data node that represents configuration, the accessible tree is the data in the NETCONF datastore where the context node exists. The root node has all top-level configuration data nodes in all modules as children.
- o If the XPath expression is defined in a substatement to a data node that represents state data, the accessible tree is all all state data on the device, and the "running" datastore. The root node has all top-level data nodes in all modules as children.
- o If the XPath expression is defined in a substatement to a "notification" statement, the accessible tree is the notification instance, all state data on the device, and the "running" datastore. The root node has the node representing the notification being defined and all top-level data nodes in all modules as children.
- o If the XPath expression is defined in a substatement to an "input" statement in an "rpc" statement, the accessible tree is the RPC operation instance, all state data on the device, and the "running" datastore. The root node has the node representing the

operation being defined and all top-level data nodes in all modules as children. The node representing the operation being defined has the operation's input parameters as children.

- o If the XPath expression is defined in a substatement to an "output" statement in an "rpc" statement, the accessible tree is the RPC operation's output, all state data on the device, and the "running" datastore. The root node has the node representing the operation being defined and all top-level data nodes in all modules as children. The node representing the operation being defined has the operation's output parameters as children.

In the accessible tree, all leafs and leaf-lists with default values in use exist (See Section 7.6.1 and Section 7.7.2).

If a node that exists in the accessible tree has a non-presence container as a child, then the non-presence container also exists in the tree.

The context node varies with the YANG XPath expression, and is specified where the YANG statement with the XPath expression is defined.

6.5. Schema Node Identifier

A schema node identifier is a string that identifies a node in the schema tree. It has two forms, "absolute" and "descendant", defined by the rules "absolute-schema-nodeid" and "descendant-schema-nodeid" in Section 13, respectively. A schema node identifier consists of a path of identifiers, separated by slashes ("/"). In an absolute schema node identifier, the first identifier after the leading slash is any top-level schema node in the local module or in all imported modules.

References to identifiers defined in external modules MUST be qualified with appropriate prefixes, and references to identifiers defined in the current module and its submodules MAY use a prefix.

For example, to identify the child node "b" of top-level node "a", the string "/a/b" can be used.

7. YANG Statements

The following sections describe all of the YANG statements.

Note that even a statement that does not have any substatements defined in YANG can have vendor-specific extensions as substatements.

For example, the "description" statement does not have any substatements defined in YANG, but the following is legal:

```
description "some text" {  
    acme:documentation-flag 5;  
}
```

7.1. The module Statement

The "module" statement defines the module's name, and groups all statements that belong to the module together. The "module" statement's argument is the name of the module, followed by a block of substatements that hold detailed module information. The module name follows the rules for identifiers in Section 6.2.

Names of modules published in RFC streams [RFC4844] MUST be assigned by IANA, see Section 15.

Private module names are assigned by the organization owning the module without a central registry. It is RECOMMENDED to choose module names that will have a low probability of colliding with standard or other enterprise modules and submodules, e.g., by using the enterprise or organization name as a prefix for the module name.

A module typically has the following layout:

```
module <module-name> {  
    // header information  
    <yang-version statement>  
    <namespace statement>  
    <prefix statement>  
  
    // linkage statements  
    <import statements>  
    <include statements>  
  
    // meta information  
    <organization statement>  
    <contact statement>  
    <description statement>  
    <reference statement>  
  
    // revision history  
    <revision statements>  
  
    // module definitions  
    <other statements>  
}
```

7.1.1.1. The module's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| anyxml | 7.10 | 0..n |
| augment | 7.16 | 0..n |
| choice | 7.9 | 0..n |
| contact | 7.1.8 | 0..1 |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| deviation | 7.19.3 | 0..n |
| extension | 7.18 | 0..n |
| feature | 7.19.1 | 0..n |
| grouping | 7.11 | 0..n |
| identity | 7.17 | 0..n |
| import | 7.1.5 | 0..n |
| include | 7.1.6 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| namespace | 7.1.3 | 1 |
| notification | 7.15 | 0..n |
| organization | 7.1.7 | 0..1 |
| prefix | 7.1.4 | 1 |
| reference | 7.20.4 | 0..1 |
| revision | 7.1.9 | 0..n |
| rpc | 7.13 | 0..n |
| typedef | 7.3 | 0..n |
| uses | 7.12 | 0..n |
| yang-version | 7.1.2 | 1 |

7.1.2. The yang-version Statement

The "yang-version" statement specifies which version of the YANG language was used in developing the module. The statement's argument is a string. It MUST contain the value "1.1", which is the current YANG version.

A module or submodule that doesn't contain the "yang-version" statement, or one that contains the value "1", is developed for YANG version 1, defined in [RFC6020].

Handling of the "yang-version" statement for versions other than "1.1" (the version defined here) is out of scope for this specification. Any document that defines a higher version will need to define the backward compatibility of such a higher version.

7.1.3. The namespace Statement

The "namespace" statement defines the XML namespace that all identifiers defined by the module are qualified by, with the exception of data node identifiers defined inside a grouping (see Section 7.12 for details). The argument to the "namespace" statement is the URI of the namespace.

See also Section 5.3.

7.1.4. The prefix Statement

The "prefix" statement is used to define the prefix associated with the module and its namespace. The "prefix" statement's argument is the prefix string that is used as a prefix to access a module. The prefix string MAY be used to refer to definitions contained in the module, e.g., "if:ifName". A prefix follows the same rules as an identifier (see Section 6.2).

When used inside the "module" statement, the "prefix" statement defines the prefix to be used when this module is imported. To improve readability of the NETCONF XML, a NETCONF client or server that generates XML or XPath that use prefixes SHOULD use the prefix defined by the module, unless there is a conflict.

When used inside the "import" statement, the "prefix" statement defines the prefix to be used when accessing definitions inside the imported module. When a reference to an identifier from the imported module is used, the prefix string for the imported module is used in combination with a colon (":") and the identifier, e.g., "if:ifIndex". To improve readability of YANG modules, the prefix defined by a module SHOULD be used when the module is imported, unless there is a conflict. If there is a conflict, i.e., two different modules that both have defined the same prefix are imported, at least one of them MUST be imported with a different prefix.

All prefixes, including the prefix for the module itself MUST be unique within the module or submodule.

7.1.5. The import Statement

The "import" statement makes definitions from one module available inside another module or submodule. The argument is the name of the module to import, and the statement is followed by a block of substatements that holds detailed import information. When a module is imported, the importing module may:

- o use any grouping and typedef defined at the top level in the imported module or its submodules.
- o use any extension, feature, and identity defined in the imported module or its submodules.
- o use any node in the imported module's schema tree in "must", "path", and "when" statements, or as the target node in "augment" and "deviation" statements.

The mandatory "prefix" substatement assigns a prefix for the imported module that is scoped to the importing module or submodule. Multiple "import" statements may be specified to import from different modules.

When the optional "revision-date" substatement is present, any typedef, grouping, extension, feature, and identity referenced by definitions in the local module are taken from the specified revision of the imported module. It is an error if the specified revision of the imported module does not exist. If no "revision-date" substatement is present, it is undefined from which revision of the module they are taken.

Multiple revisions of the same module MUST NOT be imported.

| substatement | section | cardinality |
|---------------|---------|-------------|
| prefix | 7.1.4 | 1 |
| revision-date | 7.1.5.1 | 0..1 |

The import's Substatements

7.1.5.1. The import's revision-date Statement

The import's "revision-date" statement is used to specify the exact version of the module to import. The "revision-date" statement MUST match the most recent "revision" statement in the imported module.

7.1.6. The include Statement

The "include" statement is used to make content from a submodule available to that submodule's parent module. The argument is an identifier that is the name of the submodule to include. Modules are only allowed to include submodules that belong to that module, as defined by the "belongs-to" statement (see Section 7.2.2).

Submodules are only allowed to include other submodules belonging to the same module.

When a module includes a submodule, it incorporates the contents of the submodule into the node hierarchy of the module.

For backwards compatibility with YANG version 1, a submodule is allowed to include another submodule belonging to the same module, but this is not necessary in YANG version 1.1.

When the optional "revision-date" substatement is present, the specified revision of the submodule is included in the module. It is an error if the specified revision of the submodule does not exist. If no "revision-date" substatement is present, it is undefined which revision of the submodule is included.

Multiple revisions of the same submodule MUST NOT be included.

| substatement | section | cardinality |
|---------------|---------|-------------|
| revision-date | 7.1.5.1 | 0..1 |

The includes's Substatements

7.1.7. The organization Statement

The "organization" statement defines the party responsible for this module. The argument is a string that is used to specify a textual description of the organization(s) under whose auspices this module was developed.

7.1.8. The contact Statement

The "contact" statement provides contact information for the module. The argument is a string that is used to specify contact information for the person or persons to whom technical queries concerning this module should be sent, such as their name, postal address, telephone number, and electronic mail address.

7.1.9. The revision Statement

The "revision" statement specifies the editorial revision history of the module, including the initial revision. A series of revision statements detail the changes in the module's definition. The argument is a date string in the format "YYYY-MM-DD", followed by a block of substatements that holds detailed revision information. A

module SHOULD have at least one "revision" statement. For every published editorial change, a new one SHOULD be added in front of the revisions sequence, so that all revisions are in reverse chronological order.

7.1.9.1. The revision's Substatement

| substatement | section | cardinality |
|--------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| reference | 7.20.4 | 0..1 |

7.1.10. Usage Example

```

module acme-system {
  yang-version 1.1;
  namespace "http://acme.example.com/system";
  prefix "acme";

  import ietf-yang-types {
    prefix "yang";
  }

  include acme-types;

  organization "ACME Inc.";
  contact
    "Joe L. User

    ACME, Inc.
    42 Anywhere Drive
    Nowhere, CA 95134
    USA

    Phone: +1 800 555 0100
    EMail: joe@acme.example.com";

  description
    "The module for entities implementing the ACME protocol.";

  revision "2007-06-09" {
    description "Initial revision.";
  }

  // definitions follow...
}

```

7.2. The submodule Statement

While the primary unit in YANG is a module, a YANG module can itself be constructed out of several submodules. Submodules allow a module designer to split a complex model into several pieces where all the submodules contribute to a single namespace, which is defined by the module that includes the submodules.

The "submodule" statement defines the submodule's name, and groups all statements that belong to the submodule together. The "submodule" statement's argument is the name of the submodule, followed by a block of substatements that hold detailed submodule information. The submodule name follows the rules for identifiers in Section 6.2.

Names of submodules published in RFC streams [RFC4844] MUST be assigned by IANA, see Section 15.

Private submodule names are assigned by the organization owning the submodule without a central registry. It is RECOMMENDED to choose submodule names that will have a low probability of colliding with standard or other enterprise modules and submodules, e.g., by using the enterprise or organization name as a prefix for the submodule name.

A submodule typically has the following layout:

```
submodule <module-name> {  
    <yang-version statement>
```



```
// module identification
<belongs-to statement>

// linkage statements
<import statements>

// meta information
<organization statement>
<contact statement>
<description statement>
<reference statement>

// revision history
<revision statements>

// module definitions
<other statements>
}
```

7.2.1. The submodule's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| anyxml | 7.10 | 0..n |
| augment | 7.16 | 0..n |
| belongs-to | 7.2.2 | 1 |
| choice | 7.9 | 0..n |
| contact | 7.1.8 | 0..1 |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| deviation | 7.19.3 | 0..n |
| extension | 7.18 | 0..n |
| feature | 7.19.1 | 0..n |
| grouping | 7.11 | 0..n |
| identity | 7.17 | 0..n |
| import | 7.1.5 | 0..n |
| include | 7.1.6 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| notification | 7.15 | 0..n |
| organization | 7.1.7 | 0..1 |
| reference | 7.20.4 | 0..1 |
| revision | 7.1.9 | 0..n |
| rpc | 7.13 | 0..n |
| typedef | 7.3 | 0..n |
| uses | 7.12 | 0..n |
| yang-version | 7.1.2 | 1 |

7.2.2. The belongs-to Statement

The "belongs-to" statement specifies the module to which the submodule belongs. The argument is an identifier that is the name of the module.

A submodule **MUST** only be included by the module to which it belongs, or by another submodule that belongs to that module.

The mandatory "prefix" substatement assigns a prefix for the module to which the submodule belongs. All definitions in the module that the submodule belongs to and all its submodules can be accessed by using the prefix.

| substatement | section | cardinality |
|--------------|---------|-------------|
| prefix | 7.1.4 | 1 |

The belongs-to's Substatements

7.2.3. Usage Example

```

submodule acme-types {
  yang-version 1.1;
  belongs-to "acme-system" {
    prefix "acme";
  }

  import ietf-yang-types {
    prefix "yang";
  }

  organization "ACME Inc.";
  contact
    "Joe L. User

    ACME, Inc.
    42 Anywhere Drive
    Nowhere, CA 95134
    USA

    Phone: +1 800 555 0100
    EMail: joe@acme.example.com";

  description
    "This submodule defines common ACME types.";

  revision "2007-06-09" {
    description "Initial revision.";
  }

  // definitions follows...
}

```

7.3. The typedef Statement

The "typedef" statement defines a new type that may be used locally in the module or submodule, and by other modules that import from it, according to the rules in Section 5.5. The new type is called the "derived type", and the type from which it was derived is called the

"base type". All derived types can be traced back to a YANG built-in type.

The "typedef" statement's argument is an identifier that is the name of the type to be defined, and MUST be followed by a block of substatements that holds detailed typedef information.

The name of the type MUST NOT be one of the YANG built-in types. If the typedef is defined at the top level of a YANG module or submodule, the name of the type to be defined MUST be unique within the module.

7.3.1. The typedef's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| default | 7.3.4 | 0..1 |
| description | 7.20.3 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| type | 7.3.2 | 1 |
| units | 7.3.3 | 0..1 |

7.3.2. The typedef's type Statement

The "type" statement, which MUST be present, defines the base type from which this type is derived. See Section 7.4 for details.

7.3.3. The units Statement

The "units" statement, which is optional, takes as an argument a string that contains a textual definition of the units associated with the type.

7.3.4. The typedef's default Statement

The "default" statement takes as an argument a string that contains a default value for the new type.

The value of the "default" statement MUST be valid according to the type specified in the "type" statement.

If the base type has a default value, and the new derived type does not specify a new default value, the base type's default value is also the default value of the new derived type.

If the type's default value is not valid according to the new restrictions specified in a derived type or leaf definition, the derived type or leaf definition **MUST** specify a new default value compatible with the restrictions.

7.3.5. Usage Example

```
typedef listen-ipv4-address {
  type inet:ipv4-address;
  default "0.0.0.0";
}
```

7.4. The type Statement

The "type" statement takes as an argument a string that is the name of a YANG built-in type (see Section 9) or a derived type (see Section 7.3), followed by an optional block of substatements that are used to put further restrictions on the type.

The restrictions that can be applied depend on the type being restricted. The restriction statements for all built-in types are described in the subsections of Section 9.

7.4.1. The type's Substatements

| substatement | section | cardinality |
|------------------|---------|-------------|
| base | 7.17.2 | 0..n |
| bit | 9.7.4 | 0..n |
| enum | 9.6.4 | 0..n |
| fraction-digits | 9.3.4 | 0..1 |
| length | 9.4.4 | 0..1 |
| path | 9.9.2 | 0..1 |
| pattern | 9.4.5 | 0..n |
| range | 9.2.4 | 0..1 |
| require-instance | 9.9.3 | 0..1 |
| type | 7.4 | 0..n |

7.5. The container Statement

The "container" statement is used to define an interior data node in the schema tree. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed container information.

A container node does not have a value, but it has a list of child nodes in the data tree. The child nodes are defined in the container's substatements.

7.5.1. Containers with Presence

YANG supports two styles of containers, those that exist only for organizing the hierarchy of data nodes, and those whose presence in the configuration has an explicit meaning.

In the first style, the container has no meaning of its own, existing only to contain child nodes. This is the default style.

For example, the set of scrambling options for Synchronous Optical Network (SONET) interfaces may be placed inside a "scrambling" container to enhance the organization of the configuration hierarchy, and to keep these nodes together. The "scrambling" node itself has no meaning, so removing the node when it becomes empty relieves the user from performing this task.

In the second style, the presence of the container itself is configuration data, representing a single bit of configuration data. The container acts as both a configuration knob and a means of organizing related configuration. These containers are explicitly created and deleted.

YANG calls this style a "presence container" and it is indicated using the "presence" statement, which takes as its argument a text string indicating what the presence of the node means.

For example, an "ssh" container may turn on the ability to log into the device using ssh, but can also contain any ssh-related configuration knobs, such as connection rates or retry limits.

The "presence" statement (see Section 7.5.5) is used to give semantics to the existence of the container in the data tree.

7.5.2. The container's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| action | 7.14 | 0..n |
| anyxml | 7.10 | 0..n |
| choice | 7.9 | 0..n |
| config | 7.20.1 | 0..1 |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| grouping | 7.11 | 0..n |
| if-feature | 7.19.2 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| must | 7.5.3 | 0..n |
| presence | 7.5.5 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| typedef | 7.3 | 0..n |
| uses | 7.12 | 0..n |
| when | 7.20.5 | 0..1 |

7.5.3. The must Statement

The "must" statement, which is optional, takes as an argument a string that contains an XPath expression (see Section 6.4). It is used to formally declare a constraint on valid data. The constraint is enforced according to the rules in Section 8.

When a datastore is validated, all "must" constraints are conceptually evaluated once for each data node in the accessible tree (see Section 6.4.1).

All such constraints MUST evaluate to true for the data to be valid.

The XPath expression is conceptually evaluated in the following context, in addition to the definition in Section 6.4.1:

- o The context node is the node in the accessible tree for which the "must" statement is defined.

The result of the XPath expression is converted to a boolean value using the standard XPath rules.

Note that since all leaf values in the data tree are conceptually stored in their canonical form (see Section 7.6 and Section 7.7), any XPath comparisons are done on the canonical value.

Also note that the XPath expression is conceptually evaluated. This means that an implementation does not have to use an XPath evaluator on the device. How the evaluation is done in practice is an implementation decision.

7.5.4. The must's Substatements

| substatement | section | cardinality |
|---------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| error-app-tag | 7.5.4.2 | 0..1 |
| error-message | 7.5.4.1 | 0..1 |
| reference | 7.20.4 | 0..1 |

7.5.4.1. The error-message Statement

The "error-message" statement, which is optional, takes a string as an argument. If the constraint evaluates to false, the string is passed as <error-message> in the <rpc-error>.

7.5.4.2. The error-app-tag Statement

The "error-app-tag" statement, which is optional, takes a string as an argument. If the constraint evaluates to false, the string is passed as <error-app-tag> in the <rpc-error>.

7.5.4.3. Usage Example of must and error-message


```
container interface {
  leaf ifType {
    type enumeration {
      enum ethernet;
      enum atm;
    }
  }
  leaf ifMTU {
    type uint32;
  }
  must "ifType != 'ethernet' or " +
    "(ifType = 'ethernet' and ifMTU = 1500)" {
    error-message "An ethernet MTU must be 1500";
  }
  must "ifType != 'atm' or " +
    "(ifType = 'atm' and ifMTU <= 17966 and ifMTU >= 64)" {
    error-message "An atm MTU must be 64 .. 17966";
  }
}
```

7.5.5. The presence Statement

The "presence" statement assigns a meaning to the presence of a container in the data tree. It takes as an argument a string that contains a textual description of what the node's presence means.

If a container has the "presence" statement, the container's existence in the data tree carries some meaning. Otherwise, the container is used to give some structure to the data, and it carries no meaning by itself.

See Section 7.5.1 for additional information.

7.5.6. The container's Child Node Statements

Within a container, the "container", "leaf", "list", "leaf-list", "uses", "choice", and "anyxml" statements can be used to define child nodes to the container.

7.5.7. XML Mapping Rules

A container node is encoded as an XML element. The element's local name is the container's identifier, and its namespace is the module's XML namespace (see Section 7.1.3).

The container's child nodes are encoded as subelements to the container element. If the container defines RPC input or output parameters, these subelements are encoded in the same order as they

are defined within the "container" statement. Otherwise, the subelements are encoded in any order.

A NETCONF server that replies to a <get> or <get-config> request MAY choose not to send a container element if the container node does not have the "presence" statement and no child nodes exist. Thus, a client that receives an <rpc-reply> for a <get> or <get-config> request, must be prepared to handle the case that a container node without a "presence" statement is not present in the XML.

7.5.8. NETCONF <edit-config> Operations

Containers can be created, deleted, replaced, and modified through <edit-config>, by using the "operation" attribute (see [RFC6241], Section 7.2) in the container's XML element.

If a container does not have a "presence" statement and the last child node is deleted, the NETCONF server MAY delete the container.

When a NETCONF server processes an <edit-config> request, the elements of procedure for the container node are:

If the operation is "merge" or "replace", the node is created if it does not exist.

If the operation is "create", the node is created if it does not exist. If the node already exists, a "data-exists" error is returned.

If the operation is "delete", the node is deleted if it exists. If the node does not exist, a "data-missing" error is returned.

7.5.9. Usage Example

Given the following container definition:

```
container system {
  description "Contains various system parameters";
  container services {
    description "Configure externally available services";
    container "ssh" {
      presence "Enables SSH";
      description "SSH service specific configuration";
      // more leafs, containers and stuff here...
    }
  }
}
```

A corresponding XML instance example:

```
<system>
  <services>
    <ssh/>
  </services>
</system>
```

Since the `<ssh>` element is present, ssh is enabled.

To delete a container with an `<edit-config>`:

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config">
        <services>
          <ssh nc:operation="delete"/>
        </services>
      </system>
    </config>
  </edit-config>
</rpc>
```

7.6. The leaf Statement

The "leaf" statement is used to define a leaf node in the schema tree. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed leaf information.

A leaf node has a value, but no child nodes in the data tree. Conceptually, the value in the data tree is always in the canonical form (see Section 9.1).

A leaf node exists in zero or one instances in the data tree.

The "leaf" statement is used to define a scalar variable of a particular built-in or derived type.

7.6.1. The leaf's default value

The default value of a leaf is the value that the server uses if the leaf does not exist in the data tree. The usage of the default value depends on the leaf's closest ancestor node in the schema tree that is not a non-presence container:

- o If no such ancestor exists in the schema tree, the default value MUST be used.
- o Otherwise, if this ancestor is a case node, the default value MUST be used if any node from the case exists in the data tree, or if the case node is the choice's default case, and no nodes from any other case exist in the data tree.
- o Otherwise, the default value MUST be used if the ancestor node exists in the data tree.

In these cases, the default value is said to be in use.

When the default value is in use, the server MUST operationally behave as if the leaf was present in the data tree with the default value as its value.

If a leaf has a "default" statement, the leaf's default value is the value of the "default" statement. Otherwise, if the leaf's type has a default value, and the leaf is not mandatory, then the leaf's default value is the type's default value. In all other cases, the leaf does not have a default value.

7.6.2. The leaf's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| config | 7.20.1 | 0..1 |
| default | 7.6.4 | 0..1 |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| mandatory | 7.6.5 | 0..1 |
| must | 7.5.3 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| type | 7.6.3 | 1 |
| units | 7.3.3 | 0..1 |
| when | 7.20.5 | 0..1 |

7.6.3. The leaf's type Statement

The "type" statement, which MUST be present, takes as an argument the name of an existing built-in or derived type. The optional substatements specify restrictions on this type. See Section 7.4 for details.

7.6.4. The leaf's default Statement

The "default" statement, which is optional, takes as an argument a string that contains a default value for the leaf.

The value of the "default" statement MUST be valid according to the type specified in the leaf's "type" statement.

The "default" statement MUST NOT be present on nodes where "mandatory" is true.

7.6.5. The leaf's mandatory Statement

The "mandatory" statement, which is optional, takes as an argument the string "true" or "false", and puts a constraint on valid data. If not specified, the default is "false".

If "mandatory" is "true", the behavior of the constraint depends on the type of the leaf's closest ancestor node in the schema tree that is not a non-presence container (see Section 7.5.1):

- o If no such ancestor exists in the schema tree, the leaf MUST exist.
- o Otherwise, if this ancestor is a case node, the leaf MUST exist if any node from the case exists in the data tree.
- o Otherwise, the leaf MUST exist if the ancestor node exists in the data tree.

This constraint is enforced according to the rules in Section 8.

7.6.6. XML Mapping Rules

A leaf node is encoded as an XML element. The element's local name is the leaf's identifier, and its namespace is the module's XML namespace (see Section 7.1.3).

The value of the leaf node is encoded to XML according to the type, and sent as character data in the element.

A NETCONF server that replies to a <get> or <get-config> request MAY choose not to send the leaf element if its value is the default value. Thus, a client that receives an <rpc-reply> for a <get> or <get-config> request, MUST be prepared to handle the case that a leaf node with a default value is not present in the XML. In this case, the value used by the server is known to be the default value.

See Section 7.6.8 for an example.

7.6.7. NETCONF <edit-config> Operations

When a NETCONF server processes an <edit-config> request, the elements of procedure for the leaf node are:

If the operation is "merge" or "replace", the node is created if it does not exist, and its value is set to the value found in the XML RPC data.

If the operation is "create", the node is created if it does not exist. If the node already exists, a "data-exists" error is returned.

If the operation is "delete", the node is deleted if it exists. If the node does not exist, a "data-missing" error is returned.

7.6.8. Usage Example

Given the following "leaf" statement, placed in the previously defined "ssh" container (see Section 7.5.9):

```
leaf port {  
    type inet:port-number;  
    default 22;  
    description "The port to which the SSH server listens"  
}
```

A corresponding XML instance example:

```
<port>2022</port>
```

To set the value of a leaf with an <edit-config>:

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config">
        <services>
          <ssh>
            <port>2022</port>
          </ssh>
        </services>
      </system>
    </config>
  </edit-config>
</rpc>
```

7.7. The leaf-list Statement

Where the "leaf" statement is used to define a simple scalar variable of a particular type, the "leaf-list" statement is used to define an array of a particular type. The "leaf-list" statement takes one argument, which is an identifier, followed by a block of substatements that holds detailed leaf-list information.

The values in a leaf-list MUST be unique.

Conceptually, the values in the data tree are always in the canonical form (see Section 9.1).

7.7.1. Ordering

YANG supports two styles for ordering the entries within lists and leaf-lists. In many lists, the order of list entries does not impact the implementation of the list's configuration, and the device is free to sort the list entries in any reasonable order. The "description" string for the list may suggest an order to the device implementor. YANG calls this style of list "system ordered" and they are indicated with the statement "ordered-by system".

For example, a list of valid users would typically be sorted alphabetically, since the order in which the users appeared in the configuration would not impact the creation of those users' accounts.

In the other style of lists, the order of list entries matters for the implementation of the list's configuration and the user is

responsible for ordering the entries, while the device maintains that order. YANG calls this style of list "user ordered" and they are indicated with the statement "ordered-by user".

For example, the order in which firewall filters entries are applied to incoming traffic may affect how that traffic is filtered. The user would need to decide if the filter entry that discards all TCP traffic should be applied before or after the filter entry that allows all traffic from trusted interfaces. The choice of order would be crucial.

YANG provides a rich set of facilities within NETCONF's <edit-config> operation that allows the order of list entries in user-ordered lists to be controlled. List entries may be inserted or rearranged, positioned as the first or last entry in the list, or positioned before or after another specific entry.

The "ordered-by" statement is covered in Section 7.7.7.

7.7.2. The leaf-list's default values

The default values of a leaf-list are the values that the server uses if the leaf-list does not exist in the data tree. The usage of the default values depends on the leaf-list's closest ancestor node in the schema tree that is not a non-presence container:

- o If no such ancestor exists in the schema tree, the default values MUST be used.
- o Otherwise, if this ancestor is a case node, the default values MUST be used if any node from the case exists in the data tree, or if the case node is the choice's default case, and no nodes from any other case exist in the data tree.
- o Otherwise, the default values MUST be used if the ancestor node exists in the data tree.

In these cases, the default values are said to be in use.

When the default values are in use, the server MUST operationally behave as if the leaf-list was present in the data tree with the default values as its values.

If a leaf-list has one or more "default" statement, the leaf-list's default value are the values of the "default" statements, and if the leaf-list is user-ordered, the default values are used in the order of the "default" statements. Otherwise, if the leaf-list's type has a default value, and the leaf-list does not have a "min-elements"

statement with a value greater than or equal to one, then the leaf-list's default value is the type's default value. In all other cases, the leaf-list does not have any default values.

7.7.3. The leaf-list's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| config | 7.20.1 | 0..1 |
| default | 7.7.4 | 0..n |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| max-elements | 7.7.6 | 0..1 |
| min-elements | 7.7.5 | 0..1 |
| must | 7.5.3 | 0..n |
| ordered-by | 7.7.7 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| type | 7.4 | 1 |
| units | 7.3.3 | 0..1 |
| when | 7.20.5 | 0..1 |

7.7.4. The leaf-list's default Statement

The "default" statement, which is optional, takes as an argument a string that contains a default value for the leaf-list.

The value of the "default" statement MUST be valid according to the type specified in the leaf-list's "type" statement.

The "default" statement MUST NOT be present on nodes where "min-elements" has a value greater than or equal to one.

7.7.5. The min-elements Statement

The "min-elements" statement, which is optional, takes as an argument a non-negative integer that puts a constraint on valid list entries. A valid leaf-list or list MUST have at least min-elements entries.

If no "min-elements" statement is present, it defaults to zero.

The behavior of the constraint depends on the type of the leaf-list's or list's closest ancestor node in the schema tree that is not a non-presence container (see Section 7.5.1):

- o If this ancestor is a case node, the constraint is enforced if any other node from the case exists.
- o Otherwise, it is enforced if the ancestor node exists.

The constraint is further enforced according to the rules in Section 8.

7.7.6. The max-elements Statement

The "max-elements" statement, which is optional, takes as an argument a positive integer or the string "unbounded", which puts a constraint on valid list entries. A valid leaf-list or list always has at most max-elements entries.

If no "max-elements" statement is present, it defaults to "unbounded".

The "max-elements" constraint is enforced according to the rules in Section 8.

7.7.7. The ordered-by Statement

The "ordered-by" statement defines whether the order of entries within a list are determined by the user or the system. The argument is one of the strings "system" or "user". If not present, order defaults to "system".

This statement is ignored if the list represents state data, RPC output parameters, or notification content.

See Section 7.7.1 for additional information.

7.7.7.1. ordered-by system

The entries in the list are sorted according to an unspecified order. Thus, an implementation is free to sort the entries in the most appropriate order. An implementation SHOULD use the same order for the same data, regardless of how the data were created. Using a deterministic order will make comparisons possible using simple tools like "diff".

This is the default order.

7.7.7.2. ordered-by user

The entries in the list are sorted according to an order defined by the user. This order is controlled by using special XML attributes in the <edit-config> request. See Section 7.7.9 for details.

7.7.8. XML Mapping Rules

A leaf-list node is encoded as a series of XML elements. Each element's local name is the leaf-list's identifier, and its namespace is the module's XML namespace (see Section 7.1.3).

The value of each leaf-list entry is encoded to XML according to the type, and sent as character data in the element.

The XML elements representing leaf-list entries MUST appear in the order specified by the user if the leaf-list is "ordered-by user"; otherwise, the order is implementation-dependent. The XML elements representing leaf-list entries MAY be interleaved with other sibling elements, unless the leaf-list defines RPC input or output parameters.

See Section 7.7.10 for an example.

7.7.9. NETCONF <edit-config> Operations

Leaf-list entries can be created and deleted, but not modified, through <edit-config>, by using the "operation" attribute in the leaf-list entry's XML element.

In an "ordered-by user" leaf-list, the attributes "insert" and "value" in the YANG XML namespace (Section 5.3.1) can be used to control where in the leaf-list the entry is inserted. These can be used during "create" operations to insert a new leaf-list entry, or during "merge" or "replace" operations to insert a new leaf-list entry or move an existing one.

The "insert" attribute can take the values "first", "last", "before", and "after". If the value is "before" or "after", the "value" attribute MUST also be used to specify an existing entry in the leaf-list.

If no "insert" attribute is present in the "create" operation, it defaults to "last".

If several entries in an "ordered-by user" leaf-list are modified in the same <edit-config> request, the entries are modified one at the time, in the order of the XML elements in the request.

In a <copy-config>, or an <edit-config> with a "replace" operation that covers the entire leaf-list, the leaf-list order is the same as the order of the XML elements in the request.

When a NETCONF server processes an <edit-config> request, the elements of procedure for a leaf-list node are:

If the operation is "merge" or "replace", the leaf-list entry is created if it does not exist.

If the operation is "create", the leaf-list entry is created if it does not exist. If the leaf-list entry already exists, a "data-exists" error is returned.

If the operation is "delete", the entry is deleted from the leaf-list if it exists. If the leaf-list entry does not exist, a "data-missing" error is returned.

7.7.10. Usage Example

```
leaf-list allow-user {  
    type string;  
    description "A list of user name patterns to allow";  
}
```

A corresponding XML instance example:

```
<allow-user>alice</allow-user>  
<allow-user>bob</allow-user>
```

To create a new element in this list, using the default <edit-config> operation "merge":

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config">
        <services>
          <ssh>
            <allow-user>eric</allow-user>
          </ssh>
        </services>
      </system>
    </config>
  </edit-config>
</rpc>
```

Given the following ordered-by user leaf-list:

```
leaf-list cipher {
  type string;
  ordered-by user;
  description "A list of ciphers";
}
```

The following would be used to insert a new cipher "blowfish-cbc" after "3des-cbc":

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:yang="urn:ietf:params:xml:ns:yang:1">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config">
        <services>
          <ssh>
            <cipher nc:operation="create"
              yang:insert="after"
              yang:value="3des-cbc">blowfish-cbc</cipher>
          </ssh>
        </services>
      </system>
    </config>
  </edit-config>
</rpc>
```

7.8. The list Statement

The "list" statement is used to define an interior data node in the schema tree. A list node may exist in multiple instances in the data tree. Each such instance is known as a list entry. The "list" statement takes one argument, which is an identifier, followed by a block of substatements that holds detailed list information.

A list entry is uniquely identified by the values of the list's keys, if defined.

7.8.1. The list's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| action | 7.14 | 0..n |
| anyxml | 7.10 | 0..n |
| choice | 7.9 | 0..n |
| config | 7.20.1 | 0..1 |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| grouping | 7.11 | 0..n |
| if-feature | 7.19.2 | 0..n |
| key | 7.8.2 | 0..1 |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| max-elements | 7.7.6 | 0..1 |
| min-elements | 7.7.5 | 0..1 |
| must | 7.5.3 | 0..n |
| ordered-by | 7.7.7 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| typedef | 7.3 | 0..n |
| unique | 7.8.3 | 0..n |
| uses | 7.12 | 0..n |
| when | 7.20.5 | 0..1 |

7.8.2. The list's key Statement

The "key" statement, which **MUST** be present if the list represents configuration, and **MAY** be present otherwise, takes as an argument a string that specifies a space-separated list of leaf identifiers of this list. A leaf identifier **MUST NOT** appear more than once in the key. Each such leaf identifier **MUST** refer to a child leaf of the list. The leafs can be defined directly in substatements to the list, or in groupings used in the list.

The combined values of all the leafs specified in the key are used to uniquely identify a list entry. All key leafs **MUST** be given values when a list entry is created. Thus, any default values in the key leafs or their types are ignored. It also implies that any mandatory statement in the key leafs are ignored.

A leaf that is part of the key can be of any built-in or derived type, except it **MUST NOT** be the built-in type "empty".

All key leafs in a list **MUST** have the same value for their "config" as the list itself.

The key string syntax is formally defined by the rule "key-arg" in Section 13.

7.8.3. The list's unique Statement

The "unique" statement is used to put constraints on valid list entries. It takes as an argument a string that contains a space-separated list of schema node identifiers, which MUST be given in the descendant form (see the rule "descendant-schema-nodeid" in Section 13). Each such schema node identifier MUST refer to a leaf.

If one of the referenced leafs represents configuration data, then all of the referenced leafs MUST represent configuration data.

The "unique" constraint specifies that the combined values of all the leaf instances specified in the argument string, including leafs with default values, MUST be unique within all list entry instances in which all referenced leafs exist. The constraint is enforced according to the rules in Section 8.

The unique string syntax is formally defined by the rule "unique-arg" in Section 13.

7.8.3.1. Usage Example

With the following list:

```
list server {
  key "name";
  unique "ip port";
  leaf name {
    type string;
  }
  leaf ip {
    type inet:ip-address;
  }
  leaf port {
    type inet:port-number;
  }
}
```

The following configuration is not valid:


```
<server>
  <name>smtp</name>
  <ip>192.0.2.1</ip>
  <port>25</port>
</server>
```

```
<server>
  <name>http</name>
  <ip>192.0.2.1</ip>
  <port>25</port>
</server>
```

The following configuration is valid, since the "http" and "ftp" list entries do not have a value for all referenced leafs, and are thus not taken into account when the "unique" constraint is enforced:

```
<server>
  <name>smtp</name>
  <ip>192.0.2.1</ip>
  <port>25</port>
</server>
```

```
<server>
  <name>http</name>
  <ip>192.0.2.1</ip>
</server>
```

```
<server>
  <name>ftp</name>
  <ip>192.0.2.1</ip>
</server>
```

7.8.4. The list's Child Node Statements

Within a list, the "container", "leaf", "list", "leaf-list", "uses", "choice", and "anyxml" statements can be used to define child nodes to the list.

7.8.5. XML Mapping Rules

A list is encoded as a series of XML elements, one for each entry in the list. Each element's local name is the list's identifier, and its namespace is the module's XML namespace (see Section 7.1.3).

The list's key nodes are encoded as subelements to the list's identifier element, in the same order as they are defined within the "key" statement.

The rest of the list's child nodes are encoded as subelements to the list element, after the keys. If the list defines RPC input or output parameters, the subelements are encoded in the same order as they are defined within the "list" statement. Otherwise, the subelements are encoded in any order.

The XML elements representing list entries MUST appear in the order specified by the user if the list is "ordered-by user", otherwise the order is implementation-dependent. The XML elements representing list entries MAY be interleaved with other sibling elements, unless the list defines RPC input or output parameters.

7.8.6. NETCONF <edit-config> Operations

List entries can be created, deleted, replaced, and modified through <edit-config>, by using the "operation" attribute in the list's XML element. In each case, the values of all keys are used to uniquely identify a list entry. If all keys are not specified for a list entry, a "missing-element" error is returned.

In an "ordered-by user" list, the attributes "insert" and "key" in the YANG XML namespace (Section 5.3.1) can be used to control where in the list the entry is inserted. These can be used during "create" operations to insert a new list entry, or during "merge" or "replace" operations to insert a new list entry or move an existing one.

The "insert" attribute can take the values "first", "last", "before", and "after". If the value is "before" or "after", the "key" attribute MUST also be used, to specify an existing element in the list. The value of the "key" attribute is the key predicates of the full instance identifier (see Section 9.13) for the list entry.

If no "insert" attribute is present in the "create" operation, it defaults to "last".

If several entries in an "ordered-by user" list are modified in the same <edit-config> request, the entries are modified one at the time, in the order of the XML elements in the request.

In a <copy-config>, or an <edit-config> with a "replace" operation that covers the entire list, the list entry order is the same as the order of the XML elements in the request.

When a NETCONF server processes an <edit-config> request, the elements of procedure for a list node are:

If the operation is "merge" or "replace", the list entry is created if it does not exist. If the list entry already exists

and the "insert" and "key" attributes are present, the list entry is moved according to the values of the "insert" and "key" attributes. If the list entry exists and the "insert" and "key" attributes are not present, the list entry is not moved.

If the operation is "create", the list entry is created if it does not exist. If the list entry already exists, a "data-exists" error is returned.

If the operation is "delete", the entry is deleted from the list if it exists. If the list entry does not exist, a "data-missing" error is returned.

7.8.7. Usage Example

Given the following list:

```
list user {
  key "name";
  config true;
  description "This is a list of users in the system.";

  leaf name {
    type string;
  }
  leaf type {
    type string;
  }
  leaf full-name {
    type string;
  }
}
```

A corresponding XML instance example:

```
<user>
  <name>fred</name>
  <type>admin</type>
  <full-name>Fred Flintstone</full-name>
</user>
```

To create a new user "barney":

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config">
        <user nc:operation="create">
          <name>barney</name>
          <type>admin</type>
          <full-name>Barney Rubble</full-name>
        </user>
      </system>
    </config>
  </edit-config>
</rpc>
```

To change the type of "fred" to "superuser":

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config">
        <user>
          <name>fred</name>
          <type>superuser</type>
        </user>
      </system>
    </config>
  </edit-config>
</rpc>
```

Given the following ordered-by user list:

```
list user {
  description "This is a list of users in the system.";
  ordered-by user;
  config true;

  key "name";

  leaf name {
    type string;
  }
  leaf type {
    type string;
  }
  leaf full-name {
    type string;
  }
}
```

The following would be used to insert a new user "barney" after the user "fred":

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:yang="urn:ietf:params:xml:ns:yang:1">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config"
        xmlns:ex="http://example.com/schema/config">
        <user nc:operation="create"
          yang:insert="after"
          yang:key="[ex:name='fred']">
          <name>barney</name>
          <type>admin</type>
          <full-name>Barney Rubble</full-name>
        </user>
      </system>
    </config>
  </edit-config>
</rpc>
```

The following would be used to move the user "barney" before the user "fred":

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:yang="urn:ietf:params:xml:ns:yang:1">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config"
        xmlns:ex="http://example.com/schema/config">
        <user nc:operation="merge"
          yang:insert="before"
          yang:key="[ex:name='fred']">
          <name>barney</name>
        </user>
      </system>
    </config>
  </edit-config>
</rpc>
```

7.9. The choice Statement

The "choice" statement defines a set of alternatives, only one of which may exist at any one time. The argument is an identifier, followed by a block of substatements that holds detailed choice information. The identifier is used to identify the choice node in the schema tree. A choice node does not exist in the data tree.

A choice consists of a number of branches, defined with the "case" substatement. Each branch contains a number of child nodes. The nodes from at most one of the choice's branches exist at the same time.

See Section 8.3.2 for additional information.

7.9.1. The choice's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| anyxml | 7.10 | 0..n |
| case | 7.9.2 | 0..n |
| choice | 7.9 | 0..n |
| config | 7.20.1 | 0..1 |
| container | 7.5 | 0..n |
| default | 7.9.3 | 0..1 |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| mandatory | 7.9.4 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| when | 7.20.5 | 0..1 |

7.9.2. The choice's case Statement

The "case" statement is used to define branches of the choice. It takes as an argument an identifier, followed by a block of substatements that holds detailed case information.

The identifier is used to identify the case node in the schema tree. A case node does not exist in the data tree.

Within a "case" statement, the "anyxml", "choice", "container", "leaf", "list", "leaf-list", and "uses" statements can be used to define child nodes to the case node. The identifiers of all these child nodes MUST be unique within all cases in a choice. For example, the following is illegal:

```
choice interface-type {           // This example is illegal YANG
  case a {
    leaf ethernet { ... }
  }
  case b {
    container ethernet { ...}
  }
}
```

As a shorthand, the "case" statement can be omitted if the branch contains a single "anyxml", "choice", "container", "leaf", "list", or "leaf-list" statement. In this case, the identifier of the case node

is the same as the identifier in the branch statement. The following example:

```
choice interface-type {
  container ethernet { ... }
}
```

is equivalent to:

```
choice interface-type {
  case ethernet {
    container ethernet { ... }
  }
}
```

The case identifier MUST be unique within a choice.

7.9.2.1. The case's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| anyxml | 7.10 | 0..n |
| choice | 7.9 | 0..n |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| uses | 7.12 | 0..n |
| when | 7.20.5 | 0..1 |

7.9.3. The choice's default Statement

The "default" statement indicates if a case should be considered as the default if no child nodes from any of the choice's cases exist. The argument is the identifier of the "case" statement. If the "default" statement is missing, there is no default case.

The "default" statement MUST NOT be present on choices where "mandatory" is true.

The default case is only important when considering the default values of nodes under the cases. The default values for nodes under

the default case are used if none of the nodes under any of the cases are present.

There MUST NOT be any mandatory nodes (Section 3.1) directly under the default case.

Default values for child nodes under a case are only used if one of the nodes under that case is present, or if that case is the default case. If none of the nodes under a case are present and the case is not the default case, the default values of the cases' child nodes are ignored.

In this example, the choice defaults to "interval", and the default value will be used if none of "daily", "time-of-day", or "manual" are present. If "daily" is present, the default value for "time-of-day" will be used.

```
container transfer {
  choice how {
    default interval;
    case interval {
      leaf interval {
        type uint16;
        default 30;
        units minutes;
      }
    }
    case daily {
      leaf daily {
        type empty;
      }
      leaf time-of-day {
        type string;
        units 24-hour-clock;
        default lam;
      }
    }
    case manual {
      leaf manual {
        type empty;
      }
    }
  }
}
```

7.9.4. The choice's mandatory Statement

The "mandatory" statement, which is optional, takes as an argument the string "true" or "false", and puts a constraint on valid data. If "mandatory" is "true", at least one node from exactly one of the choice's case branches MUST exist.

If not specified, the default is "false".

The behavior of the constraint depends on the type of the choice's closest ancestor node in the schema tree which is not a non-presence container (see Section 7.5.1):

- o If this ancestor is a case node, the constraint is enforced if any other node from the case exists.
- o Otherwise, it is enforced if the ancestor node exists.

The constraint is further enforced according to the rules in Section 8.

7.9.5. XML Mapping Rules

The choice and case nodes are not visible in XML.

The child nodes of the selected "case" statement MUST be encoded in the same order as they are defined in the "case" statement if they are part of an RPC input or output parameter definition. Otherwise, the subelements are encoded in any order.

7.9.6. NETCONF <edit-config> Operations

Since only one of the choice's cases can be valid at any time, the creation of a node from one case implicitly deletes all nodes from all other cases. If an <edit-config> operation creates a node from a case, the NETCONF server will delete any existing nodes that are defined in other cases inside the choice.

7.9.7. Usage Example

Given the following choice:

```
container protocol {
  choice name {
    case a {
      leaf udp {
        type empty;
      }
    }
    case b {
      leaf tcp {
        type empty;
      }
    }
  }
}
```

A corresponding XML instance example:

```
<protocol>
  <tcp/>
</protocol>
```

To change the protocol from tcp to udp:

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit-config>
    <target>
      <running/>
    </target>
    <config>
      <system xmlns="http://example.com/schema/config">
        <protocol>
          <udp nc:operation="create"/>
        </protocol>
      </system>
    </config>
  </edit-config>
</rpc>
```

7.10. The anyxml Statement

The "anyxml" statement defines an interior node in the schema tree. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed anyxml information.

The "anyxml" statement is used to represent an unknown chunk of XML. No restrictions are placed on the XML. This can be useful, for

example, in RPC replies. An example is the <filter> parameter in the <get-config> operation.

An anyxml node cannot be augmented (see Section 7.16).

Since the use of anyxml limits the manipulation of the content, it is RECOMMENDED that the "anyxml" statement not be used to represent configuration data.

An anyxml node exists in zero or one instances in the data tree.

7.10.1. The anyxml's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| config | 7.20.1 | 0..1 |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| mandatory | 7.6.5 | 0..1 |
| must | 7.5.3 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| when | 7.20.5 | 0..1 |

7.10.2. XML Mapping Rules

An anyxml node is encoded as an XML element. The element's local name is the anyxml's identifier, and its namespace is the module's XML namespace (see Section 7.1.3). The value of the anyxml node is encoded as XML content of this element.

Note that any prefixes used in the encoding are local to each instance encoding. This means that the same XML may be encoded differently by different implementations.

7.10.3. NETCONF <edit-config> Operations

An anyxml node is treated as an opaque chunk of data. This data can be modified in its entirety only.

Any "operation" attributes present on subelements of an anyxml node are ignored by the NETCONF server.

When a NETCONF server processes an <edit-config> request, the elements of procedure for the anyxml node are:

If the operation is "merge" or "replace", the node is created if it does not exist, and its value is set to the XML content of the anyxml node found in the XML RPC data.

If the operation is "create", the node is created if it does not exist, and its value is set to the XML content of the anyxml node found in the XML RPC data. If the node already exists, a "data-exists" error is returned.

If the operation is "delete", the node is deleted if it exists. If the node does not exist, a "data-missing" error is returned.

7.10.4. Usage Example

Given the following "anyxml" statement:

```
anyxml data;
```

The following are two valid encodings of the same anyxml value:

```
<data xmlns:if="http://example.com/ns/interface">
  <if:interface>
    <if:ifIndex>1</if:ifIndex>
  </if:interface>
</data>

<data>
  <interface xmlns="http://example.com/ns/interface">
    <ifIndex>1</ifIndex>
  </interface>
</data>
```

7.11. The grouping Statement

The "grouping" statement is used to define a reusable block of nodes, which may be used locally in the module or submodule, and by other modules that import from it, according to the rules in Section 5.5. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed grouping information.

The "grouping" statement is not a data definition statement and, as such, does not define any nodes in the schema tree.

A grouping is like a "structure" or a "record" in conventional programming languages.

Once a grouping is defined, it can be referenced in a "uses" statement (see Section 7.12). A grouping MUST NOT reference itself, neither directly nor indirectly through a chain of other groupings.

If the grouping is defined at the top level of a YANG module or submodule, the grouping's identifier MUST be unique within the module.

A grouping is more than just a mechanism for textual substitution, but defines a collection of nodes. Identifiers appearing inside the grouping are resolved relative to the scope in which the grouping is defined, not where it is used. Prefix mappings, type names, grouping names, and extension usage are evaluated in the hierarchy where the "grouping" statement appears. For extensions, this means that extensions are applied to the grouping node, not the uses node.

7.11.1. The grouping's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| action | 7.14 | 0..n |
| anyxml | 7.10 | 0..n |
| choice | 7.9 | 0..n |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| grouping | 7.11 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| typedef | 7.3 | 0..n |
| uses | 7.12 | 0..n |

7.11.2. Usage Example

```

import ietf-inet-types {
    prefix "inet";
}

grouping endpoint {
    description "A reusable endpoint group.";
    leaf ip {
        type inet:ip-address;
    }
    leaf port {
        type inet:port-number;
    }
}

```

7.12. The uses Statement

The "uses" statement is used to reference a "grouping" definition. It takes one argument, which is the name of the grouping.

The effect of a "uses" reference to a grouping is that the nodes defined by the grouping are copied into the current schema tree, and then updated according to the "refine" and "augment" statements.

The identifiers defined in the grouping are not bound to a namespace until the contents of the grouping are added to the schema tree via a "uses" statement that does not appear inside a "grouping" statement, at which point they are bound to the namespace of the current module.

7.12.1. The uses's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| augment | 7.16 | 0..n |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| refine | 7.12.2 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| when | 7.20.5 | 0..1 |

7.12.2. The refine Statement

Some of the properties of each node in the grouping can be refined with the "refine" statement. The argument is a string that identifies a node in the grouping. This node is called the refine's target node. If a node in the grouping is not present as a target

node of a "refine" statement, it is not refined, and thus used exactly as it was defined in the grouping.

The argument string is a descendant schema node identifier (see Section 6.5).

The following refinements can be done:

- o A leaf or choice node may get a default value, or a new default value if it already had one.
- o Any node may get a specialized "description" string.
- o Any node may get a specialized "reference" string.
- o Any node may get a different "config" statement.
- o A leaf, anyxml, or choice node may get a different "mandatory" statement.
- o A container node may get a "presence" statement.
- o A leaf, leaf-list, list, container, or anyxml node may get additional "must" expressions.
- o A leaf-list or list node may get a different "min-elements" or "max-elements" statement.
- o A leaf, leaf-list, list, container, or anyxml node may get additional "if-feature" expressions.

7.12.3. XML Mapping Rules

Each node in the grouping is encoded as if it was defined inline, even if it is imported from another module with another XML namespace.

7.12.4. Usage Example

To use the "endpoint" grouping defined in Section 7.11.2 in a definition of an HTTP server in some other module, we can do:


```
import acme-system {
  prefix "acme";
}

container http-server {
  leaf name {
    type string;
  }
  uses acme:endpoint;
}
```

A corresponding XML instance example:

```
<http-server>
  <name>extern-web</name>
  <ip>192.0.2.1</ip>
  <port>80</port>
</http-server>
```

If port 80 should be the default for the HTTP server, default can be added:

```
container http-server {
  leaf name {
    type string;
  }
  uses acme:endpoint {
    refine port {
      default 80;
    }
  }
}
```

If we want to define a list of servers, and each server has the ip and port as keys, we can do:

```
list server {
  key "ip port";
  leaf name {
    type string;
  }
  uses acme:endpoint;
}
```

The following is an error:

```

    container http-server {
        uses acme:endpoint;
        leaf ip {           // illegal - same identifier "ip" used twice
            type string;
        }
    }

```

7.13. The rpc Statement

The "rpc" statement is used to define an RPC operation. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed rpc information. This argument is the name of the RPC, and is used as the element name directly under the <rpc> element, as designated by the substitution group "rpcOperation" in [RFC6241].

The "rpc" statement defines an rpc node in the schema tree. Under the rpc node, a schema node with the name "input", and a schema node with the name "output" are also defined. The nodes "input" and "output" are defined in the module's namespace.

7.13.1. The rpc's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| grouping | 7.11 | 0..n |
| if-feature | 7.19.2 | 0..n |
| input | 7.13.2 | 0..1 |
| output | 7.13.3 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| typedef | 7.3 | 0..n |

7.13.2. The input Statement

The "input" statement, which is optional, is used to define input parameters to the operation. It does not take an argument. The substatements to "input" define nodes under the operation's input node.

If a leaf in the input tree has a "mandatory" statement with the value "true", the leaf **MUST** be present in a NETCONF RPC invocation. Otherwise, the server **MUST** return a "missing-element" error.

If a leaf in the input tree has a default value, the NETCONF server MUST use this value in the same cases as described in Section 7.6.1. In these cases, the server MUST operationally behave as if the leaf was present in the NETCONF RPC invocation with the default value as its value.

If a leaf-list in the input tree has one or more default values, the NETCONF server MUST use these values in the same cases as described in Section 7.7.2. In these cases, the server MUST operationally behave as if the leaf-list was present in the NETCONF RPC invocation with the default values as its values.

If a "config" statement is present for any node in the input tree, the "config" statement is ignored.

If any node has a "when" statement that would evaluate to false, then this node MUST NOT be present in the input tree.

7.13.2.1. The input's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| anyxml | 7.10 | 0..n |
| choice | 7.9 | 0..n |
| container | 7.5 | 0..n |
| grouping | 7.11 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| must | 7.5.3 | 0..n |
| typedef | 7.3 | 0..n |
| uses | 7.12 | 0..n |

7.13.3. The output Statement

The "output" statement, which is optional, is used to define output parameters to the RPC operation. It does not take an argument. The substatements to "output" define nodes under the operation's output node.

If a leaf in the output tree has a "mandatory" statement with the value "true", the leaf MUST be present in a NETCONF RPC reply.

If a leaf in the output tree has a default value, the NETCONF client MUST use this value in the same cases as described in Section 7.6.1. In these cases, the client MUST operationally behave as if the leaf

was present in the NETCONF RPC reply with the default value as its value.

If a leaf-list in the output tree has one or more default values, the NETCONF client MUST use these values in the same cases as described in Section 7.7.2. In these cases, the client MUST operationally behave as if the leaf-list was present in the NETCONF RPC reply with the default values as its values.

If a "config" statement is present for any node in the output tree, the "config" statement is ignored.

If any node has a "when" statement that would evaluate to false, then this node MUST NOT be present in the output tree.

7.13.3.1. The output's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| anyxml | 7.10 | 0..n |
| choice | 7.9 | 0..n |
| container | 7.5 | 0..n |
| grouping | 7.11 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| must | 7.5.3 | 0..n |
| typedef | 7.3 | 0..n |
| uses | 7.12 | 0..n |

7.13.4. XML Mapping Rules

An rpc node is encoded as a child XML element to the <rpc> element defined in [RFC6241]. The element's local name is the rpc's identifier, and its namespace is the module's XML namespace (see Section 7.1.3).

Input parameters are encoded as child XML elements to the rpc node's XML element, in the same order as they are defined within the "input" statement.

If the RPC operation invocation succeeded, and no output parameters are returned, the <rpc-reply> contains a single <ok/> element defined in [RFC6241]. If output parameters are returned, they are encoded as child elements to the <rpc-reply> element defined in [RFC6241], in the same order as they are defined within the "output" statement.

7.13.5. Usage Example

The following example defines an RPC operation:

```
module rock {
  yang-version 1.1;
  namespace "http://example.net/rock";
  prefix "rock";

  rpc rock-the-house {
    input {
      leaf zip-code {
        type string;
      }
    }
  }
}
```

A corresponding XML instance example of the complete rpc and rpc-reply:

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <rock-the-house xmlns="http://example.net/rock">
    <zip-code>27606-0100</zip-code>
  </rock-the-house>
</rpc>

<rpc-reply message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <ok/>
</rpc-reply>
```

7.14. The action Statement

The "action" statement is used to define an operation connected to a specific container or list data node. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed action information. The argument is the name of the action.

The "action" statement defines an action node in the schema tree. Under the action node, a schema node with the name "input", and a schema node with the name "output" are also defined. The nodes "input" and "output" are defined in the module's namespace.

An action MUST NOT be defined within an rpc, another action or a notification, i.e., an action node MUST NOT have an rpc, action, or a notification node as one of its ancestors in the schema tree. For

example, this means that it is an error if a grouping that contains an action is used in a notification definition.

The difference between an action and an rpc is that an action is tied to a node in the data tree, whereas an rpc is not. When an action is invoked, the node in the data tree is specified along with the name of the action and the input parameters.

7.14.1. The action's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| grouping | 7.11 | 0..n |
| if-feature | 7.19.2 | 0..n |
| input | 7.13.2 | 0..1 |
| output | 7.13.3 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| typedef | 7.3 | 0..n |

7.14.2. XML Mapping Rules

When an action is invoked, an element with the local name "action" in the namespace "urn:ietf:params:xml:ns:yang:1" (see Section 5.3.1) is encoded as a child XML element to the <rpc> element defined in [RFC6241], as designated by the substitution group "rpcOperation" in [RFC6241].

The "action" element contains an hierarchy of nodes that identifies the node in the data tree. It MUST contain all containers and list nodes from the top level down to the list or container containing the action. For lists, all key leafs MUST also be included. The last container or list contains an XML element that carries the name of the defined action. Within this element the input parameters are encoded as child XML elements, in the same order as they are defined within the "input" statement.

Only one action can be invoked in one <rpc>. If more than one actions are present in the <rpc>, the server MUST reply with an "bad-element" error-tag in the <rpc-error>.

If the action operation invocation succeeded, and no output parameters are returned, the <rpc-reply> contains a single <ok/> element defined in [RFC6241]. If output parameters are returned, they are encoded as child elements to the <rpc-reply> element defined

in [RFC6241], in the same order as they are defined within the "output" statement.

7.14.3. Usage Example

The following example defines an action to reset one server at a server farm:

```
module server-farm {
  yang-version 1.1;
  namespace "http://example.net/server-farm";
  prefix "sfarm";

  import ietf-yang-types {
    prefix "yang";
  }

  list server {
    key name;
    leaf name {
      type string;
    }
    action reset {
      input {
        leaf reset-at {
          type yang:date-and-time;
          mandatory true;
        }
      }
      output {
        leaf reset-finished-at {
          type yang:date-and-time;
          mandatory true;
        }
      }
    }
  }
}
```

A corresponding XML instance example of the complete rpc and rpc-reply:

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <action xmlns="urn:ietf:params:xml:ns:yang:1">
    <server xmlns="http://example.net/server-farm">
      <name>apache-1</name>
      <reset>
        <reset-at>2014-07-29T13:42:00Z</reset-at>
      </reset>
    </server>
  </action>
</rpc>

<rpc-reply message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <reset-finished-at xmlns="http://example.net/server-farm">
    2014-07-29T13:42:12Z
  </reset-at>
</rpc-reply>
```

7.15. The notification Statement

The "notification" statement is used to define a NETCONF notification. It takes one argument, which is an identifier, followed by a block of substatements that holds detailed notification information. The "notification" statement defines a notification node in the schema tree.

If a leaf in the notification tree has a "mandatory" statement with the value "true", the leaf MUST be present in a NETCONF notification.

If a leaf in the notification tree has a default value, the NETCONF client MUST use this value in the same cases as described in Section 7.6.1. In these cases, the client MUST operationally behave as if the leaf was present in the NETCONF notification with the default value as its value.

If a leaf-list in the notification tree has one or more default values, the NETCONF client MUST use these values in the same cases as described in Section 7.7.2. In these cases, the client MUST operationally behave as if the leaf-list was present in the NETCONF notification with the default values as its values.

If a "config" statement is present for any node in the notification tree, the "config" statement is ignored.

7.15.1. The notification's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| anyxml | 7.10 | 0..n |
| choice | 7.9 | 0..n |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| grouping | 7.11 | 0..n |
| if-feature | 7.19.2 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| must | 7.5.3 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| typedef | 7.3 | 0..n |
| uses | 7.12 | 0..n |

7.15.2. XML Mapping Rules

A notification node is encoded as a child XML element to the <notification> element defined in NETCONF Event Notifications [RFC5277]. The element's local name is the notification's identifier, and its namespace is the module's XML namespace (see Section 7.1.3).

7.15.3. Usage Example

The following example defines a notification:

```

module event {
  yang-version 1.1;
  namespace "http://example.com/event";
  prefix "ev";

  notification event {
    leaf event-class {
      type string;
    }
    anyxml reporting-entity;
    leaf severity {
      type string;
    }
  }
}

```

A corresponding XML instance example of the complete notification:

```
<notification
  xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
  <eventTime>2008-07-08T00:01:00Z</eventTime>
  <event xmlns="http://example.com/event">
    <event-class>fault</event-class>
    <reporting-entity>
      <card>Ethernet0</card>
    </reporting-entity>
    <severity>major</severity>
  </event>
</notification>
```

7.16. The augment Statement

The "augment" statement allows a module or submodule to add to the schema tree defined in an external module, or the current module and its submodules, and to add to the nodes from a grouping in a "uses" statement. The argument is a string that identifies a node in the schema tree. This node is called the augment's target node. The target node MUST be either a container, list, choice, case, input, output, or notification node. It is augmented with the nodes defined in the substatements that follow the "augment" statement.

The argument string is a schema node identifier (see Section 6.5). If the "augment" statement is on the top level in a module or submodule, the absolute form (defined by the rule "absolute-schema-nodeid" in Section 13) of a schema node identifier MUST be used. If the "augment" statement is a substatement to the "uses" statement, the descendant form (defined by the rule "descendant-schema-nodeid" in Section 13) MUST be used.

If the target node is a container, list, case, input, output, or notification node, the "container", "leaf", "list", "leaf-list", "uses", and "choice" statements can be used within the "augment" statement.

If the target node is a choice node, the "case" statement, or a case shorthand statement (see Section 7.9.2) can be used within the "augment" statement.

If the target node is in another module, then nodes added by the augmentation MUST NOT be mandatory nodes (see Section 3.1).

The "augment" statement MUST NOT add multiple nodes with the same name from the same module to the target node.

7.16.1. The augment's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| action | 7.14 | 0..n |
| anyxml | 7.10 | 0..n |
| case | 7.9.2 | 0..n |
| choice | 7.9 | 0..n |
| container | 7.5 | 0..n |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| leaf | 7.6 | 0..n |
| leaf-list | 7.7 | 0..n |
| list | 7.8 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| uses | 7.12 | 0..n |
| when | 7.20.5 | 0..1 |

7.16.2. XML Mapping Rules

All data nodes defined in the "augment" statement are defined as XML elements in the XML namespace of the module where the "augment" is specified.

When a node is augmented, the augmenting child nodes are encoded as subelements to the augmented node, in any order.

7.16.3. Usage Example

In namespace `http://example.com/schema/interfaces`, we have:

```
container interfaces {  
  list ifEntry {  
    key "ifIndex";  
  
    leaf ifIndex {  
      type uint32;  
    }  
    leaf ifDescr {  
      type string;  
    }  
    leaf ifType {  
      type iana:IfType;  
    }  
    leaf ifMtu {  
      type int32;  
    }  
  }  
}
```

Then, in namespace `http://example.com/schema/ds0`, we have:

```
import interface-module {  
  prefix "if";  
}  
augment "/if:interfaces/if:ifEntry" {  
  when "if:ifType='ds0'";  
  leaf ds0ChannelNumber {  
    type ChannelNumber;  
  }  
}
```

A corresponding XML instance example:

```
<interfaces xmlns="http://example.com/schema/interfaces"  
  xmlns:ds0="http://example.com/schema/ds0">  
  <ifEntry>  
    <ifIndex>1</ifIndex>  
    <ifDescr>Flintstone Inc Ethernet A562</ifDescr>  
    <ifType>ethernetCsmacd</ifType>  
    <ifMtu>1500</ifMtu>  
  </ifEntry>  
  <ifEntry>  
    <ifIndex>2</ifIndex>  
    <ifDescr>Flintstone Inc DS0</ifDescr>  
    <ifType>ds0</ifType>  
    <ds0:ds0ChannelNumber>1</ds0:ds0ChannelNumber>  
  </ifEntry>  
</interfaces>
```

As another example, suppose we have the choice defined in Section 7.9.7. The following construct can be used to extend the protocol definition:

```
augment /ex:system/ex:protocol/ex:name {  
  case c {  
    leaf smtp {  
      type empty;  
    }  
  }  
}
```

A corresponding XML instance example:

```
<ex:system>  
  <ex:protocol>  
    <ex:tcp/>  
  </ex:protocol>  
</ex:system>
```

or

```
<ex:system>  
  <ex:protocol>  
    <other:smtp/>  
  </ex:protocol>  
</ex:system>
```

7.17. The identity Statement

The "identity" statement is used to define a new globally unique, abstract, and untyped identity. Its only purpose is to denote its name, semantics, and existence. An identity can either be defined from scratch or derived from one or more base identities. The identity's argument is an identifier that is the name of the identity. It is followed by a block of substatements that holds detailed identity information.

The built-in datatype "identityref" (see Section 9.10) can be used to reference identities within a data model.

7.17.1. The identity's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| base | 7.17.2 | 0..n |
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |

7.17.2. The base Statement

The "base" statement, which is optional, takes as an argument a string that is the name of an existing identity, from which the new identity is derived. If no "base" statement is present, the identity is defined from scratch. If multiple "base" statements are present, the identity is derived from all of them.

If a prefix is present on the base name, it refers to an identity defined in the module that was imported with that prefix, or the local module if the prefix matches the local module's prefix. Otherwise, an identity with the matching name **MUST** be defined in the current module or an included submodule.

An identity **MUST NOT** reference itself, neither directly nor indirectly through a chain of other identities.

The derivation of identities has the following properties:

- o It is irreflexive, which means that an identity is not derived from itself.
- o It is transitive, which means that if identity B is derived from A and C is derived from B, then C is also derived from A.

7.17.3. Usage Example

```
module crypto-base {
  yang-version 1.1;
  namespace "http://example.com/crypto-base";
  prefix "crypto";

  identity crypto-alg {
    description
      "Base identity from which all crypto algorithms
       are derived.";
  }
}

module des {
  yang-version 1.1;
  namespace "http://example.com/des";
  prefix "des";

  import "crypto-base" {
    prefix "crypto";
  }

  identity des {
    base "crypto:crypto-alg";
    description "DES crypto algorithm";
  }

  identity des3 {
    base "crypto:crypto-alg";
    description "Triple DES crypto algorithm";
  }
}
```

7.18. The extension Statement

The "extension" statement allows the definition of new statements within the YANG language. This new statement definition can be imported and used by other modules.

The statement's argument is an identifier that is the new keyword for the extension and must be followed by a block of substatements that holds detailed extension information. The purpose of the "extension" statement is to define a keyword, so that it can be imported and used by other modules.

The extension can be used like a normal YANG statement, with the statement name followed by an argument if one is defined by the "extension" statement, and an optional block of substatements. The statement's name is created by combining the prefix of the module in

which the extension was defined, a colon (":"), and the extension's keyword, with no interleaving whitespace. The substatements of an extension are defined by the "extension" statement, using some mechanism outside the scope of this specification. Syntactically, the substatements MUST be YANG statements, or also extensions defined using "extension" statements. YANG statements in extensions MUST follow the syntactical rules in Section 13.

7.18.1. The extension's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| argument | 7.18.2 | 0..1 |
| description | 7.20.3 | 0..1 |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |

7.18.2. The argument Statement

The "argument" statement, which is optional, takes as an argument a string that is the name of the argument to the keyword. If no argument statement is present, the keyword expects no argument when it is used.

The argument's name is used in the YIN mapping, where it is used as an XML attribute or element name, depending on the argument's "yin-element" statement.

7.18.2.1. The argument's Substatements

| substatement | section | cardinality |
|--------------|----------|-------------|
| yin-element | 7.18.2.2 | 0..1 |

7.18.2.2. The yin-element Statement

The "yin-element" statement, which is optional, takes as an argument the string "true" or "false". This statement indicates if the argument is mapped to an XML element in YIN or to an XML attribute (see Section 12).

If no "yin-element" statement is present, it defaults to "false".

7.18.3. Usage Example

To define an extension:

```
module my-extensions {  
    ...  
  
    extension c-define {  
        description  
            "Takes as argument a name string.  
            Makes the code generator use the given name in the  
            #define.";  
        argument "name";  
    }  
}
```

To use the extension:

```
module my-interfaces {  
    ...  
    import my-extensions {  
        prefix "myext";  
    }  
    ...  
  
    container interfaces {  
        ...  
        myext:c-define "MY_INTERFACES";  
    }  
}
```

7.19. Conformance-Related Statements

This section defines statements related to conformance, as described in Section 5.6.

7.19.1. The feature Statement

The "feature" statement is used to define a mechanism by which portions of the schema are marked as conditional. A feature name is defined that can later be referenced using the "if-feature" statement (see Section 7.19.2). Schema nodes tagged with an "if-feature" statement are ignored by the device unless the device supports the given feature expression. This allows portions of the YANG module to be conditional based on conditions on the device. The model can represent the abilities of the device within the model, giving a richer model that allows for differing device abilities and roles.

The argument to the "feature" statement is the name of the new feature, and follows the rules for identifiers in Section 6.2. This name is used by the "if-feature" statement to tie the schema nodes to the feature.

In this example, a feature called "local-storage" represents the ability for a device to store syslog messages on local storage of some sort. This feature is used to make the "local-storage-limit" leaf conditional on the presence of some sort of local storage. If the device does not report that it supports this feature, the "local-storage-limit" node is not supported.

```
module syslog {
  ...
  feature local-storage {
    description
      "This feature means the device supports local
       storage (memory, flash or disk) that can be used to
       store syslog messages.";
  }

  container syslog {
    leaf local-storage-limit {
      if-feature local-storage;
      type uint64;
      units "kilobyte";
      config false;
      description
        "The amount of local storage that can be
         used to hold syslog messages.";
    }
  }
}
```

The "if-feature" statement can be used in many places within the YANG syntax. Definitions tagged with "if-feature" are ignored when the device does not support that feature.

A feature MUST NOT reference itself, neither directly nor indirectly through a chain of other features.

In order for a device to implement a feature that is dependent on any other features (i.e., the feature has one or more "if-feature" substatements), the device MUST also implement all the dependant features.

7.19.1.1. The feature's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| status | 7.20.2 | 0..1 |
| reference | 7.20.4 | 0..1 |

7.19.2. The if-feature Statement

The "if-feature" statement makes its parent statement conditional. The argument is a boolean expression over feature names. In this expression, a feature name evaluates to "true" if and only if the feature is implemented by the server. The parent statement is implemented by servers where the boolean expression evaluates to "true".

The if-feature boolean expression syntax is formally defined by the rule "if-feature-expr" in Section 13. When this boolean expression is evaluated, the operator order of precedence is (highest precedence first): "not", "and", "or".

If a prefix is present on a feature name in the boolean expression, the prefixed name refers to a feature defined in the module that was imported with that prefix, or the local module if the prefix matches the local module's prefix. Otherwise, a feature with the matching name **MUST** be defined in the current module or an included submodule.

A leaf that is a list key **MUST NOT** have any "if-feature" statements, unless the conditions specified in the "if-feature" statements are the same as the "if-feature" conditions in effect on the leaf's parent node.

7.19.2.1. Usage Example

In this example, the container "target" is implemented if any of the features "outbound-tls" or "outbound-ssh" is implemented by the server.

```

container target {
    if-feature "outbound-tls or outbound-ssh";
    ...
}

```

7.19.3. The deviation Statement

The "deviation" statement defines a hierarchy of a module that the device does not implement faithfully. The argument is a string that identifies the node in the schema tree where a deviation from the module occurs. This node is called the deviation's target node. The contents of the "deviation" statement give details about the deviation.

The argument string is an absolute schema node identifier (see Section 6.5).

Deviations define the way a device or class of devices deviate from a standard. This means that deviations **MUST** never be part of a published standard, since they are the mechanism for learning how implementations vary from the standards.

Device deviations are strongly discouraged and **MUST** only be used as a last resort. Telling the application how a device fails to follow a standard is no substitute for implementing the standard correctly. A device that deviates from a module is not fully compliant with the module.

However, in some cases, a particular device may not have the hardware or software ability to support parts of a standard module. When this occurs, the device makes a choice either to treat attempts to configure unsupported parts of the module as an error that is reported back to the unsuspecting application or ignore those incoming requests. Neither choice is acceptable.

Instead, YANG allows devices to document portions of a base module that are not supported or supported but with different syntax, by using the "deviation" statement.

7.19.3.1. The deviation's Substatements

| substatement | section | cardinality |
|--------------|----------|-------------|
| description | 7.20.3 | 0..1 |
| deviate | 7.19.3.2 | 1..n |
| reference | 7.20.4 | 0..1 |

7.19.3.2. The deviate Statement

The "deviate" statement defines how the device's implementation of the target node deviates from its original definition. The argument is one of the strings "not-supported", "add", "replace", or "delete".

The argument "not-supported" indicates that the target node is not implemented by this device.

The argument "add" adds properties to the target node. The properties to add are identified by substatements to the "deviate" statement. If a property can only appear once, the property MUST NOT exist in the target node.

The argument "replace" replaces properties of the target node. The properties to replace are identified by substatements to the "deviate" statement. The properties to replace MUST exist in the target node.

The argument "delete" deletes properties from the target node. The properties to delete are identified by substatements to the "delete" statement. The substatement's keyword MUST match a corresponding keyword in the target node, and the argument's string MUST be equal to the corresponding keyword's argument string in the target node.

| substatement | section | cardinality |
|--------------|-------------|-------------|
| config | 7.20.1 | 0..1 |
| default | 7.6.4 7.7.4 | 0..n |
| mandatory | 7.6.5 | 0..1 |
| max-elements | 7.7.6 | 0..1 |
| min-elements | 7.7.5 | 0..1 |
| must | 7.5.3 | 0..n |
| type | 7.4 | 0..1 |
| unique | 7.8.3 | 0..n |
| units | 7.3.3 | 0..1 |

The deviate's Substatements

7.19.3.3. Usage Example

In this example, the device is informing client applications that it does not support the "daytime" service in the style of RFC 867.

```
deviation /base:system/base:daytime {  
    deviate not-supported;  
}
```

The following example sets a device-specific default value to a leaf that does not have a default value defined:

```
deviation /base:system/base:user/base:type {  
    deviate add {  
        default "admin"; // new users are 'admin' by default  
    }  
}
```

In this example, the device limits the number of name servers to 3:

```
deviation /base:system/base:name-server {  
    deviate replace {  
        max-elements 3;  
    }  
}
```

If the original definition is:

```
container system {  
    must "daytime or time";  
    ...  
}
```

a device might remove this must constraint by doing:

```
deviation "/base:system" {  
    deviate delete {  
        must "daytime or time";  
    }  
}
```

7.20. Common Statements

This section defines substatements common to several other statements.

7.20.1. The config Statement

The "config" statement takes as an argument the string "true" or "false". If "config" is "true", the definition represents configuration. Data nodes representing configuration will be part of the reply to a <get-config> request, and can be sent in a <copy-config> or <edit-config> request.

If "config" is "false", the definition represents state data. Data nodes representing state data will be part of the reply to a <get>, but not to a <get-config> request, and cannot be sent in a <copy-config> or <edit-config> request.

If "config" is not specified, the default is the same as the parent schema node's "config" value. If the parent node is a "case" node, the value is the same as the "case" node's parent "choice" node.

If the top node does not specify a "config" statement, the default is "true".

If a node has "config" set to "false", no node underneath it can have "config" set to "true".

7.20.2. The status Statement

The "status" statement takes as an argument one of the strings "current", "deprecated", or "obsolete".

- o "current" means that the definition is current and valid.
- o "deprecated" indicates an obsolete definition, but it permits new/continued implementation in order to foster interoperability with older/existing implementations.
- o "obsolete" means the definition is obsolete and SHOULD NOT be implemented and/or can be removed from implementations.

If no status is specified, the default is "current".

If a definition is "current", it MUST NOT reference a "deprecated" or "obsolete" definition within the same module.

If a definition is "deprecated", it MUST NOT reference an "obsolete" definition within the same module.

For example, the following is illegal:

```
typedef my-type {
    status deprecated;
    type int32;
}

leaf my-leaf {
    status current;
    type my-type; // illegal, since my-type is deprecated
}
```

7.20.3. The description Statement

The "description" statement takes as an argument a string that contains a human-readable textual description of this definition. The text is provided in a language (or languages) chosen by the module developer; for the sake of interoperability, it is RECOMMENDED to choose a language that is widely understood among the community of network administrators who will use the module.

7.20.4. The reference Statement

The "reference" statement takes as an argument a string that is used to specify a textual cross-reference to an external document, either another module that defines related management information, or a document that provides additional information relevant to this definition.

For example, a typedef for a "uri" data type could look like:

```
typedef uri {  
    type string;  
    reference  
        "RFC 3986: Uniform Resource Identifier (URI): Generic Syntax";  
    ...  
}
```

7.20.5. The when Statement

The "when" statement makes its parent data definition statement conditional. The node defined by the parent data definition statement is only valid when the condition specified by the "when" statement is satisfied. The statement's argument is an XPath expression (see Section 6.4), which is used to formally specify this condition. If the XPath expression conceptually evaluates to "true" for a particular instance, then the node defined by the parent data definition statement is valid; otherwise, it is not.

A leaf that is a list key MUST NOT have a "when" statement, unless the condition specified in the "when" statement is the same as the "when" condition in effect on the leaf's parent node.

See Section 8.3.2 for additional information.

The XPath expression is conceptually evaluated in the following context, in addition to the definition in Section 6.4.1:

- o If the "when" statement is a child of an "augment" statement, then the context node is the augment's target node in the data tree, if

the target node is a data node. Otherwise, the context node is the closest ancestor node to the target node that is also a data node.

- o If the "when" statement is a child of a "uses", "choice", or "case" statement, then the context node is the closest ancestor node to the "uses", "choice", or "case" node that is also a data node.
- o If the "when" statement is a child of any other data definition statement, the context node is the node in the accessible tree for which the "when" statement is defined.

The result of the XPath expression is converted to a boolean value using the standard XPath rules.

If the XPath expression references any node that also has associated "when" statements, these "when" expressions MUST be evaluated first. There MUST NOT be any circular dependencies in these "when" expressions.

Note that the XPath expression is conceptually evaluated. This means that an implementation does not have to use an XPath evaluator on the device. The "when" statement can very well be implemented with specially written code.

8. Constraints

8.1. Constraints on Data

Several YANG statements define constraints on valid data. These constraints are enforced in different ways, depending on what type of data the statement defines.

- o If the constraint is defined on configuration data, it MUST be true in a valid configuration data tree.
- o If the constraint is defined on state data, it MUST be true in a reply to a <get> operation without a filter.
- o If the constraint is defined on notification content, it MUST be true in any notification instance.
- o If the constraint is defined on RPC input parameters, it MUST be true in an invocation of the RPC operation.
- o If the constraint is defined on RPC output parameters, it MUST be true in the RPC reply.

8.2. Hierarchy of Constraints

Conditions on parent nodes affect constraints on child nodes as a natural consequence of the hierarchy of nodes. "must", "mandatory", "min-elements", and "max-elements" constraints are not enforced if the parent node has a "when" or "if-feature" property that is not satisfied on the current device.

In this example, the "mandatory" constraint on the "longitude" leaf is not enforced on devices that lack the "has-gps" feature:

```
container location {
  if-feature has-gps;
  leaf longitude {
    mandatory true;
    ...
  }
}
```

8.3. Constraint Enforcement Model

For configuration data, there are three windows when constraints MUST be enforced:

- o during parsing of RPC payloads
- o during processing of NETCONF operations
- o during validation

Each of these scenarios is considered in the following sections.

8.3.1. Payload Parsing

When content arrives in RPC payloads, it MUST be well-formed XML, following the hierarchy and content rules defined by the set of models the device implements.

- o If a leaf data value does not match the type constraints for the leaf, including those defined in the type's "range", "length", and "pattern" properties, the server MUST reply with an "invalid-value" error-tag in the rpc-error, and with the error-app-tag and error-message associated with the constraint, if any exist.
- o If all keys of a list entry are not present, the server MUST reply with a "missing-element" error-tag in the rpc-error.

- o If data for more than one case branch of a choice is present, the server MUST reply with a "bad-element" in the rpc-error.
- o If data for a node tagged with "if-feature" is present, and the if-feature expression evaluates to "false" on the device, the server MUST reply with an "unknown-element" error-tag in the rpc-error.
- o If data for a node tagged with "when" is present, and the "when" condition evaluates to "false", the server MUST reply with an "unknown-element" error-tag in the rpc-error.
- o For insert handling, if the value for the attributes "before" and "after" are not valid for the type of the appropriate key leafs, the server MUST reply with a "bad-attribute" error-tag in the rpc-error.
- o If the attributes "before" and "after" appears in any element that is not a list whose "ordered-by" property is "user", the server MUST reply with an "unknown-attribute" error-tag in the rpc-error.

8.3.2. NETCONF <edit-config> Processing

After the incoming data is parsed, the NETCONF server performs the <edit-config> operation by applying the data to the configuration datastore. During this processing, the following errors MUST be detected:

- o Delete requests for non-existent data.
- o Create requests for existent data.
- o Insert requests with "before" or "after" parameters that do not exist.

During <edit-config> processing:

- o If the NETCONF operation creates data nodes under a "choice", any existing nodes from other "case" branches are deleted by the server.
- o If the NETCONF operation modifies a data node such that any node's "when" expression becomes false, then the node with the "when" expression is deleted by the server.

8.3.3. Validation

When datastore processing is complete, the final contents MUST obey all validation constraints. This validation processing is performed at differing times according to the datastore. If the datastore is "running" or "startup", these constraints MUST be enforced at the end of the <edit-config> or <copy-config> operation. If the datastore is "candidate", the constraint enforcement is delayed until a <commit> or <validate> operation.

- o Any "must" constraints MUST evaluate to "true".
- o Any referential integrity constraints defined via the "path" statement MUST be satisfied.
- o Any "unique" constraints on lists MUST be satisfied.
- o The "min-elements" and "max-elements" constraints are enforced for lists and leaf-lists.

9. Built-In Types

YANG has a set of built-in types, similar to those of many programming languages, but with some differences due to special requirements from the management information model.

Additional types may be defined, derived from those built-in types or from other derived types. Derived types may use subtyping to formally restrict the set of possible values.

The different built-in types and their derived types allow different kinds of subtyping, namely length and regular expression restrictions of strings (Section 9.4.4, Section 9.4.5) and range restrictions of numeric types (Section 9.2.4).

The lexical representation of a value of a certain type is used in the NETCONF messages and when specifying default values and numerical ranges in YANG modules.

9.1. Canonical Representation

For most types, there is a single canonical representation of the type's values. Some types allow multiple lexical representations of the same value, for example, the positive integer "17" can be represented as "+17" or "17". Implementations MUST support all lexical representations specified in this document.

When a NETCONF server sends data, it MUST be in the canonical form.

Some types have a lexical representation that depends on the XML context in which they occur. These types do not have a canonical form.

9.2. The Integer Built-In Types

The integer built-in types are `int8`, `int16`, `int32`, `int64`, `uint8`, `uint16`, `uint32`, and `uint64`. They represent signed and unsigned integers of different sizes:

`int8` represents integer values between -128 and 127, inclusively.

`int16` represents integer values between -32768 and 32767, inclusively.

`int32` represents integer values between -2147483648 and 2147483647, inclusively.

`int64` represents integer values between -9223372036854775808 and 9223372036854775807, inclusively.

`uint8` represents integer values between 0 and 255, inclusively.

`uint16` represents integer values between 0 and 65535, inclusively.

`uint32` represents integer values between 0 and 4294967295, inclusively.

`uint64` represents integer values between 0 and 18446744073709551615, inclusively.

9.2.1. Lexical Representation

An integer value is lexically represented as an optional sign ("+" or "-"), followed by a sequence of decimal digits. If no sign is specified, "+" is assumed.

For convenience, when specifying a default value for an integer in a YANG module, an alternative lexical representation can be used, which represents the value in a hexadecimal or octal notation. The hexadecimal notation consists of an optional sign ("+" or "-"), the characters "0x" followed a number of hexadecimal digits, where letters may be uppercase or lowercase. The octal notation consists of an optional sign ("+" or "-"), the character "0" followed a number of octal digits.

Note that if a default value in a YANG module has a leading zero ("0"), it is interpreted as an octal number. In the XML instance

documents, an integer is always interpreted as a decimal number, and leading zeros are allowed.

Examples:

```
// legal values
+4711                // legal positive value
4711                 // legal positive value
-123                 // legal negative value
0xf00f               // legal positive hexadecimal value
-0xf                 // legal negative hexadecimal value
052                  // legal positive octal value

// illegal values
- 1                  // illegal intermediate space
```

9.2.2. Canonical Form

The canonical form of a positive integer does not include the sign "+". Leading zeros are prohibited. The value zero is represented as "0".

9.2.3. Restrictions

All integer types can be restricted with the "range" statement (Section 9.2.4).

9.2.4. The range Statement

The "range" statement, which is an optional substatement to the "type" statement, takes as an argument a range expression string. It is used to restrict integer and decimal built-in types, or types derived from those.

A range consists of an explicit value, or a lower-inclusive bound, two consecutive dots "..", and an upper-inclusive bound. Multiple values or ranges can be given, separated by "|". If multiple values or ranges are given, they all MUST be disjoint and MUST be in ascending order. If a range restriction is applied to an already range-restricted type, the new restriction MUST be equal or more limiting, that is raising the lower bounds, reducing the upper bounds, removing explicit values or ranges, or splitting ranges into multiple ranges with intermediate gaps. Each explicit value and range boundary value given in the range expression MUST match the type being restricted, or be one of the special values "min" or "max". "min" and "max" mean the minimum and maximum value accepted for the type being restricted, respectively.

The range expression syntax is formally defined by the rule "range-arg" in Section 13.

9.2.4.1. The range's Substatements

| substatement | section | cardinality |
|---------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| error-app-tag | 7.5.4.2 | 0..1 |
| error-message | 7.5.4.1 | 0..1 |
| reference | 7.20.4 | 0..1 |

9.2.5. Usage Example

```
typedef my-base-int32-type {
    type int32 {
        range "1..4 | 10..20";
    }
}

typedef my-type1 {
    type my-base-int32-type {
        // legal range restriction
        range "11..max"; // 11..20
    }
}

typedef my-type2 {
    type my-base-int32-type {
        // illegal range restriction
        range "11..100";
    }
}
```

9.3. The decimal64 Built-In Type

The decimal64 type represents a subset of the real numbers, which can be represented by decimal numerals. The value space of decimal64 is the set of numbers that can be obtained by multiplying a 64-bit signed integer by a negative power of ten, i.e., expressible as " $i \times 10^{-n}$ " where i is an integer64 and n is an integer between 1 and 18, inclusively.

9.3.1. Lexical Representation

A decimal64 value is lexically represented as an optional sign ("+" or "-"), followed by a sequence of decimal digits, optionally followed by a period ('.') as a decimal indicator and a sequence of decimal digits. If no sign is specified, "+" is assumed.

9.3.2. Canonical Form

The canonical form of a positive decimal64 does not include the sign "+". The decimal point is required. Leading and trailing zeros are prohibited, subject to the rule that there MUST be at least one digit before and after the decimal point. The value zero is represented as "0.0".

9.3.3. Restrictions

A decimal64 type can be restricted with the "range" statement (Section 9.2.4).

9.3.4. The fraction-digits Statement

The "fraction-digits" statement, which is a substatement to the "type" statement, MUST be present if the type is "decimal64". It takes as an argument an integer between 1 and 18, inclusively. It controls the size of the minimum difference between values of a decimal64 type, by restricting the value space to numbers that are expressible as $i \times 10^{-n}$ where n is the fraction-digits argument.

The following table lists the minimum and maximum value for each fraction-digit value:

| fraction-digit | min | max |
|----------------|-----------------------|----------------------|
| 1 | -922337203685477580.8 | 922337203685477580.7 |
| 2 | -92233720368547758.08 | 92233720368547758.07 |
| 3 | -9223372036854775.808 | 9223372036854775.807 |
| 4 | -922337203685477.5808 | 922337203685477.5807 |
| 5 | -92233720368547.75808 | 92233720368547.75807 |
| 6 | -9223372036854.775808 | 9223372036854.775807 |
| 7 | -922337203685.4775808 | 922337203685.4775807 |
| 8 | -92233720368.54775808 | 92233720368.54775807 |
| 9 | -9223372036.854775808 | 9223372036.854775807 |
| 10 | -922337203.6854775808 | 922337203.6854775807 |
| 11 | -92233720.36854775808 | 92233720.36854775807 |
| 12 | -9223372.036854775808 | 9223372.036854775807 |
| 13 | -922337.2036854775808 | 922337.2036854775807 |
| 14 | -92233.72036854775808 | 92233.72036854775807 |
| 15 | -9223.372036854775808 | 9223.372036854775807 |
| 16 | -922.3372036854775808 | 922.3372036854775807 |
| 17 | -92.23372036854775808 | 92.23372036854775807 |
| 18 | -9.223372036854775808 | 9.223372036854775807 |

9.3.5. Usage Example

```

typedef my-decimal {
    type decimal64 {
        fraction-digits 2;
        range "1 .. 3.14 | 10 | 20..max";
    }
}

```

9.4. The string Built-In Type

The string built-in type represents human-readable strings in YANG. Legal characters are the Unicode and ISO/IEC 10646 [ISO.10646] characters, including tab, carriage return, and line feed but excluding the other C0 control characters, the surrogate blocks, and the noncharacters. The string syntax is formally defined by the rule "yang-string" in Section 13.

9.4.1. Lexical Representation

A string value is lexically represented as character data in the XML instance documents.

9.4.2. Canonical Form

The canonical form is the same as the lexical representation. No Unicode normalization is performed of string values.

9.4.3. Restrictions

A string can be restricted with the "length" (Section 9.4.4) and "pattern" (Section 9.4.5) statements.

9.4.4. The length Statement

The "length" statement, which is an optional substatement to the "type" statement, takes as an argument a length expression string. It is used to restrict the built-in types "string" and "binary" or types derived from them.

A "length" statement restricts the number of Unicode characters in the string.

A length range consists of an explicit value, or a lower bound, two consecutive dots "..", and an upper bound. Multiple values or ranges can be given, separated by "|". Length-restricting values MUST NOT be negative. If multiple values or ranges are given, they all MUST be disjoint and MUST be in ascending order. If a length restriction is applied to an already length-restricted type, the new restriction MUST be equal or more limiting, that is, raising the lower bounds, reducing the upper bounds, removing explicit length values or ranges, or splitting ranges into multiple ranges with intermediate gaps. A length value is a non-negative integer, or one of the special values "min" or "max". "min" and "max" mean the minimum and maximum length accepted for the type being restricted, respectively. An implementation is not required to support a length value larger than 18446744073709551615.

The length expression syntax is formally defined by the rule "length-arg" in Section 13.

9.4.4.1. The length's Substatements

| substatement | section | cardinality |
|---------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| error-app-tag | 7.5.4.2 | 0..1 |
| error-message | 7.5.4.1 | 0..1 |
| reference | 7.20.4 | 0..1 |

9.4.5. The pattern Statement

The "pattern" statement, which is an optional substatement to the "type" statement, takes as an argument a regular expression string, as defined in [XSD-TYPES]. It is used to restrict the built-in type "string", or types derived from "string", to values that match the pattern.

If the type has multiple "pattern" statements, the expressions are ANDed together, i.e., all such expressions have to match.

If a pattern restriction is applied to an already pattern-restricted type, values must match all patterns in the base type, in addition to the new patterns.

9.4.5.1. The pattern's Substatements

| substatement | section | cardinality |
|---------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| error-app-tag | 7.5.4.2 | 0..1 |
| error-message | 7.5.4.1 | 0..1 |
| modifier | 9.4.6 | 0..1 |
| reference | 7.20.4 | 0..1 |

9.4.6. The modifier Statement

9.4.7. Usage Example

With the following typedef:

```
typedef my-base-str-type {
  type string {
    length "1..255";
  }
}
```

the following refinement is legal:

```
type my-base-str-type {
  // legal length refinement
  length "11 | 42..max"; // 11 | 42..255
}
```

and the following refinement is illegal:

```
type my-base-str-type {  
    // illegal length refinement  
    length "1..999";  
}
```

With the following type:

```
type string {  
    length "0..4";  
    pattern "[0-9a-fA-F]*";  
}
```

the following strings match:

```
AB          // legal  
9A00        // legal
```

and the following strings do not match:

```
00ABAB      // illegal, too long  
xx00        // illegal, bad characters
```

With the following type:

```
typedef yang-identifier {  
    type string {  
        length "1..max";  
        pattern '[a-zA-Z_][a-zA-Z0-9\_\-\.]*';  
        pattern '[xX][mM][lL].*' {  
            modifier invert-match;  
        }  
    }  
}
```

the following string match:

```
enabled      // legal
```

and the following strings do not match:

```
10-mbit      // illegal, starts with a number  
xml-element  // illegal, starts with illegal sequence
```

9.5. The boolean Built-In Type

The boolean built-in type represents a boolean value.

9.5.1. Lexical Representation

The lexical representation of a boolean value is a string with a value of "true" or "false". These values MUST be in lowercase.

9.5.2. Canonical Form

The canonical form is the same as the lexical representation.

9.5.3. Restrictions

A boolean cannot be restricted.

9.6. The enumeration Built-In Type

The enumeration built-in type represents values from a set of assigned names.

9.6.1. Lexical Representation

The lexical representation of an enumeration value is the assigned name string.

9.6.2. Canonical Form

The canonical form is the assigned name string.

9.6.3. Restrictions

An enumeration can be restricted with the "enum" (Section 9.6.4) statement.

9.6.4. The enum Statement

The "enum" statement, which is a substatement to the "type" statement, MUST be present if the type is "enumeration". It is repeatedly used to specify each assigned name of an enumeration type. It takes as an argument a string which is the assigned name. The string MUST NOT be empty and MUST NOT have any leading or trailing whitespace characters. The use of Unicode control codes SHOULD be avoided.

The statement is optionally followed by a block of substatements that holds detailed enum information.

All assigned names in an enumeration MUST be unique.

When an existing enumeration type is restricted, the set of assigned names in the new type MUST be a subset of the base type's set of assigned names. The value of such an assigned name MUST not be changed.

9.6.4.1. The enum's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| value | 9.6.4.2 | 0..1 |

9.6.4.2. The value Statement

The "value" statement, which is optional, is used to associate an integer value with the assigned name for the enum. This integer value MUST be in the range -2147483648 to 2147483647, and it MUST be unique within the enumeration type.

If a value is not specified, then one will be automatically assigned. If the "enum" substatement is the first one defined, the assigned value is zero (0); otherwise, the assigned value is one greater than the current highest enum value (i.e., the highest enum value, implicit or explicit, prior to the current "enum" substatement in the parent "type" statement).

If the current highest value is equal to 2147483647, then an enum value MUST be specified for "enum" substatements following the one with the current highest value.

When an existing enumeration type is restricted, the "value" statement MUST either have the same value as the in the base type or not be present, in which case the value is the same as in the base type.

9.6.5. Usage Example

```
leaf myenum {  
    type enumeration {  
        enum zero;  
        enum one;  
        enum seven {  
            value 7;  
        }  
    }  
}
```

The lexical representation of the leaf "myenum" with value "seven" is:

```
<myenum>seven</myenum>
```

With the following typedef:

```
typedef my-base-enumeration-type {  
    type enumeration {  
        enum white {  
            value 1;  
        }  
        enum yellow {  
            value 2;  
        }  
        enum red {  
            value 3;  
        }  
    }  
}
```

the following refinement is legal:

```
type my-base-enumeration-type {  
    // legal enum refinement  
    enum yellow;  
    enum red {  
        value 3;  
    }  
}
```

and the following refinement is illegal:

```
type my-base-enumeration-type {  
    // illegal enum refinement  
    enum yellow {  
        value 4; // illegal value change  
    }  
    enum black; // illegal addition of new name  
}
```

9.7. The bits Built-In Type

The bits built-in type represents a bit set. That is, a bits value is a set of flags identified by small integer position numbers starting at 0. Each bit number has an assigned name.

9.7.1. Restrictions

A bits type cannot be restricted.

9.7.2. Lexical Representation

The lexical representation of the bits type is a space-separated list of the individual bit values that are set. An empty string thus represents a value where no bits are set.

9.7.3. Canonical Form

In the canonical form, the bit values are separated by a single space character and they appear ordered by their position (see Section 9.7.4.2).

9.7.4. The bit Statement

The "bit" statement, which is a substatement to the "type" statement, MUST be present if the type is "bits". It is repeatedly used to specify each assigned named bit of a bits type. It takes as an argument a string that is the assigned name of the bit. It is followed by a block of substatements that holds detailed bit information. The assigned name follows the same syntax rules as an identifier (see Section 6.2).

All assigned names in a bits type MUST be unique.

9.7.4.1. The bit's Substatements

| substatement | section | cardinality |
|--------------|---------|-------------|
| description | 7.20.3 | 0..1 |
| if-feature | 7.19.2 | 0..n |
| reference | 7.20.4 | 0..1 |
| status | 7.20.2 | 0..1 |
| position | 9.7.4.2 | 0..1 |

9.7.4.2. The position Statement

The "position" statement, which is optional, takes as an argument a non-negative integer value that specifies the bit's position within a hypothetical bit field. The position value **MUST** be in the range 0 to 4294967295, and it **MUST** be unique within the bits type. The value is unused by YANG and the NETCONF messages, but is carried as a convenience to implementors.

If a bit position is not specified, then one will be automatically assigned. If the "bit" substatement is the first one defined, the assigned value is zero (0); otherwise, the assigned value is one greater than the current highest bit position (i.e., the highest bit position, implicit or explicit, prior to the current "bit" substatement in the parent "type" statement).

If the current highest bit position value is equal to 4294967295, then a position value **MUST** be specified for "bit" substatements following the one with the current highest position value.

9.7.5. Usage Example

Given the following leaf:

```
leaf mybits {
  type bits {
    bit disable-nagle {
      position 0;
    }
    bit auto-sense-speed {
      position 1;
    }
    bit ten-Mb-only {
      position 2;
    }
  }
  default "auto-sense-speed";
}
```

The lexical representation of this leaf with bit values disable-nagle and ten-Mb-only set would be:

```
<mybits>disable-nagle ten-Mb-only</mybits>
```

9.8. The binary Built-In Type

The binary built-in type represents any binary data, i.e., a sequence of octets.

9.8.1. Restrictions

A binary can be restricted with the "length" (Section 9.4.4) statement. The length of a binary value is the number of octets it contains.

9.8.2. Lexical Representation

Binary values are encoded with the base64 encoding scheme (see [RFC4648], Section 4).

9.8.3. Canonical Form

The canonical form of a binary value follows the rules in [RFC4648].

9.9. The leafref Built-In Type

The leafref type is used to declare a constraint on the value space of a leaf, based on a reference to a set of leaf instances in the data tree. The "path" substatement (Section 9.9.2) selects a set of leaf instances, and the leafref value space is the set of values of these leaf instances.

If the leaf with the leafref type represents configuration data, and the "require-instance" property (Section 9.9.3) is "true", the leaf it refers to MUST also represent configuration. Such a leaf puts a constraint on valid data. All such nodes MUST reference existing leaf instances or leaves with default values in use (see Section 7.6.1 and Section 7.7.2) for the data to be valid. This constraint is enforced according to the rules in Section 8.

There MUST NOT be any circular chains of leafrefs.

If the leaf that the leafref refers to is conditional based on one or more features (see Section 7.19.2), then the leaf with the leafref type MUST also be conditional based on at least the same set of features.

9.9.1. Restrictions

A leafref can be restricted with the "require-instance" statement (Section 9.9.3).

9.9.2. The path Statement

The "path" statement, which is a substatement to the "type" statement, MUST be present if the type is "leafref". It takes as an argument a string that MUST refer to a leaf or leaf-list node.

The syntax for a path argument is a subset of the XPath abbreviated syntax. Predicates are used only for constraining the values for the key nodes for list entries. Each predicate consists of exactly one equality test per key, and multiple adjacent predicates MAY be present if a list has multiple keys. The syntax is formally defined by the rule "path-arg" in Section 13.

The predicates are only used when more than one key reference is needed to uniquely identify a leaf instance. This occurs if a list has multiple keys, or a reference to a leaf other than the key in a list is needed. In these cases, multiple leafrefs are typically specified, and predicates are used to tie them together.

The "path" expression evaluates to a node set consisting of zero, one, or more nodes. If the leaf with the leafref type represents configuration data, this node set MUST be non-empty.

The "path" XPath expression is conceptually evaluated in the following context, in addition to the definition in Section 6.4.1:

- o If the "path" statement is defined within a typedef, the context node is the leaf or leaf-list node in the data tree that references the typedef.
- o Otherwise, the context node is the node in the data tree for which the "path" statement is defined.

9.9.3. The require-instance Statement

The "require-instance" statement, which is a substatement to the "type" statement, MAY be present if the type is "instance-identifier" or "leafref". It takes as an argument the string "true" or "false". If this statement is not present, it defaults to "true".

If "require-instance" is "true", it means that the instance being referred MUST exist for the data to be valid. This constraint is enforced according to the rules in Section 8.

If "require-instance" is "false", it means that the instance being referred MAY exist in valid data.

9.9.4. Lexical Representation

A leafref value is encoded the same way as the leaf it references.

9.9.5. Canonical Form

The canonical form of a leafref is the same as the canonical form of the leaf it references.

9.9.6. Usage Example

With the following list:

```
list interface {
  key "name";
  leaf name {
    type string;
  }
  leaf admin-status {
    type admin-status;
  }
  list address {
    key "ip";
    leaf ip {
      type yang:ip-address;
    }
  }
}
```

The following leafref refers to an existing interface:

```
leaf mgmt-interface {
  type leafref {
    path "../interface/name";
  }
}
```

An example of a corresponding XML snippet:

```
<interface>
  <name>eth0</name>
</interface>
<interface>
  <name>lo</name>
</interface>

<mgmt-interface>eth0</mgmt-interface>
```

The following leafrefs refer to an existing address of an interface:

```
container default-address {
  leaf ifname {
    type leafref {
      path "../../interface/name";
    }
  }
  leaf address {
    type leafref {
      path "../../interface[name = current()../ifname]"
        + "/address/ip";
    }
  }
}
```

An example of a corresponding XML snippet:

```
<interface>
  <name>eth0</name>
  <admin-status>up</admin-status>
  <address>
    <ip>192.0.2.1</ip>
  </address>
  <address>
    <ip>192.0.2.2</ip>
  </address>
</interface>
<interface>
  <name>lo</name>
  <admin-status>up</admin-status>
  <address>
    <ip>127.0.0.1</ip>
  </address>
</interface>

<default-address>
  <ifname>eth0</ifname>
  <address>192.0.2.2</address>
</default-address>
```

The following list uses a leafref for one of its keys. This is similar to a foreign key in a relational database.

```
list packet-filter {
  key "if-name filter-id";
  leaf if-name {
    type leafref {
      path "/interface/name";
    }
  }
  leaf filter-id {
    type uint32;
  }
  ...
}
```

An example of a corresponding XML snippet:

```
<interface>
  <name>eth0</name>
  <admin-status>up</admin-status>
  <address>
    <ip>192.0.2.1</ip>
  </address>
  <address>
    <ip>192.0.2.2</ip>
  </address>
</interface>

<packet-filter>
  <if-name>eth0</if-name>
  <filter-id>1</filter-id>
  ...
</packet-filter>
<packet-filter>
  <if-name>eth0</if-name>
  <filter-id>2</filter-id>
  ...
</packet-filter>
```

The following notification defines two leafrefs to refer to an existing admin-status:

```
notification link-failure {
  leaf if-name {
    type leafref {
      path "/interface/name";
    }
  }
  leaf admin-status {
    type leafref {
      path
        "/interface[name = current()../if-name]"
        + "/admin-status";
    }
  }
}
```

An example of a corresponding XML notification:

```
<notification
  xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
  <eventTime>2008-04-01T00:01:00Z</eventTime>
  <link-failure xmlns="http://acme.example.com/system">
    <if-name>eth0</if-name>
    <admin-status>up</admin-status>
  </link-failure>
</notification>
```

9.10. The identityref Built-In Type

The identityref type is used to reference an existing identity (see Section 7.17).

9.10.1. Restrictions

An identityref cannot be restricted.

9.10.2. The identityref's base Statement

The "base" statement, which is a substatement to the "type" statement, MUST be present at least once if the type is "identityref". The argument is the name of an identity, as defined by an "identity" statement. If a prefix is present on the identity name, it refers to an identity defined in the module that was imported with that prefix. Otherwise, an identity with the matching name MUST be defined in the current module or an included submodule.

Valid values for an identityref are any identities derived from all the identityref's base identities. On a particular server, the valid values are further restricted to the set of identities defined in the modules supported by the server.

9.10.3. Lexical Representation

An identityref is encoded as the referred identity's qualified name as defined in [XML-NAMES]. If the prefix is not present, the namespace of the identityref is the default namespace in effect on the element that contains the identityref value.

When an identityref is given a default value using the "default" statement, the identity name in the default value MAY have a prefix. If a prefix is present on the identity name, it refers to an identity defined in the module that was imported with that prefix, or the prefix for the current module if the identity is defined in the current module or one of its submodules. Otherwise, an identity with the matching name MUST be defined in the current module or one of its submodules.

The string value of a node of type `identityref` in a "must" or "when" XPath expression is the referred identity's qualified name with the prefix present. If the referred identity is defined in an imported module, the prefix in the string value is the prefix defined in the corresponding "import" statement. Otherwise, the prefix in the string value is the prefix for the current module.

9.10.4. Canonical Form

Since the lexical form depends on the XML context in which the value occurs, this type does not have a canonical form.

9.10.5. Usage Example

With the identity definitions in Section 7.17.3 and the following module:

```
module my-crypto {
  yang-version 1.1;
  namespace "http://example.com/my-crypto";
  prefix mc;

  import "crypto-base" {
    prefix "crypto";
  }

  identity aes {
    base "crypto:crypto-alg";
  }

  leaf crypto {
    type identityref {
      base "crypto:crypto-alg";
    }
  }

  container aes-parameters {
    when "../crypto = 'mc:aes'";
    ...
  }
}
```

the following is an example how the leaf "crypto" can be encoded, if the value is the "des3" identity defined in the "des" module:

```
<crypto xmlns:des="http://example.com/des">des:des3</crypto>
```

Any prefixes used in the encoding are local to each instance encoding. This means that the same identityref may be encoded differently by different implementations. For example, the following example encodes the same leaf as above:

```
<crypto xmlns:x="http://example.com/des">x:des3</crypto>
```

If the "crypto" leaf's value instead is "aes" defined in the "my-crypto" module, it can be encoded as:

```
<crypto xmlns:mc="http://example.com/my-crypto">mc:aes</crypto>
```

or, using the default namespace:

```
<crypto>aes</crypto>
```

9.11. The empty Built-In Type

The empty built-in type represents a leaf that does not have any value, it conveys information by its presence or absence.

An empty type cannot have a default value.

9.11.1. Restrictions

An empty type cannot be restricted.

9.11.2. Lexical Representation

Not applicable.

9.11.3. Canonical Form

Not applicable.

9.11.4. Usage Example

With the following leaf

```
leaf enable-qos {  
    type empty;  
}
```

the following is an example of a valid encoding

```
<enable-qos/>
```

if the leaf exists.

9.12. The union Built-In Type

The union built-in type represents a value that corresponds to one of its member types.

When the type is "union", the "type" statement (Section 7.4) MUST be present. It is used to repeatedly specify each member type of the union. It takes as an argument a string that is the name of a member type.

A member type can be of any built-in or derived type.

A value representing a union data type is validated consecutively against each member type, in the order they are specified in the "type" statement, until a match is found. The type that matched will be the type of the value for the node that was validated.

Any default value or "units" property defined in the member types is not inherited by the union type.

9.12.1. Restrictions

A union cannot be restricted. However, each member type can be restricted, based on the rules defined in Section 9.

9.12.2. Lexical Representation

The lexical representation of a union is a value that corresponds to the representation of any one of the member types.

9.12.3. Canonical Form

The canonical form of a union value is the same as the canonical form of the member type of the value.

9.12.4. Usage Example

The following is a union of an int32 and an enumeration:

```
type union {  
  type int32;  
  type enumeration {  
    enum "unbounded";  
  }  
}
```

Care must be taken when a member type is a leafref where the "require-instance" property (Section 9.9.3) is "true". If a leaf of

such a type refers to an existing instance, the leaf's value must be re-validated if the target instance is deleted. For example, with the following definitions:

```
list filter {
  key name;
  leaf name {
    type string;
  }
  ...
}

leaf outbound-filter {
  type union {
    type leafref {
      path "/filter/name";
    }
    type enumeration {
      enum default-filter;
    }
  }
}
```

assume that there exists an entry in the filter list with the name "http", and that the outbound-filter leaf has this value:

```
<filter>
  <name>http</name>
</filter>
<outbound-filter>http</outbound-filter>
```

If the filter entry "http" is removed, the outbound-filter leaf's value doesn't match the leafref, and the next member type is checked. The current value ("http") doesn't match the enumeration, so the resulting configuration is invalid.

If the second member type in the union had been of type "string" instead of an enumeration, the current value would have matched, and the resulting configuration would have been valid.

9.13. The instance-identifier Built-In Type

The instance-identifier built-in type is used to uniquely identify a particular instance node in the data tree.

The syntax for an instance-identifier is a subset of the XPath abbreviated syntax, formally defined by the rule "instance-identifier" in Section 13. It is used to uniquely identify

a node in the data tree. Predicates are used only for specifying the values for the key nodes for list entries, a value of a leaf-list entry, or a positional index for a list without keys. For identifying list entries with keys, each predicate consists of one equality test per key, and each key MUST have a corresponding predicate.

If the leaf with the instance-identifier type represents configuration data, and the "require-instance" property (Section 9.9.3) is "true", the node it refers to MUST also represent configuration. Such a leaf puts a constraint on valid data. All such leaf nodes MUST reference existing nodes or leaf or leaf-list nodes with their default value in use (see Section 7.6.1 and Section 7.7.2) for the data to be valid. This constraint is enforced according to the rules in Section 8.

The "instance-identifier" XPath expression is conceptually evaluated in the following context, in addition to the definition in Section 6.4.1:

- o The context node is the root node in the accessible tree.

9.13.1. Restrictions

An instance-identifier can be restricted with the "require-instance" statement (Section 9.9.3).

9.13.2. Lexical Representation

An instance-identifier value is lexically represented as a string. All node names in an instance-identifier value MUST be qualified with explicit namespace prefixes, and these prefixes MUST be declared in the XML namespace scope in the instance-identifier's XML element.

Any prefixes used in the encoding are local to each instance encoding. This means that the same instance-identifier may be encoded differently by different implementations.

9.13.3. Canonical Form

Since the lexical form depends on the XML context in which the value occurs, this type does not have a canonical form.

9.13.4. Usage Example

The following are examples of instance identifiers:

```
/* instance-identifier for a container */
/ex:system/ex:services/ex:ssh

/* instance-identifier for a leaf */
/ex:system/ex:services/ex:ssh/ex:port

/* instance-identifier for a list entry */
/ex:system/ex:user[ex:name='fred']

/* instance-identifier for a leaf in a list entry */
/ex:system/ex:user[ex:name='fred']/ex:type

/* instance-identifier for a list entry with two keys */
/ex:system/ex:server[ex:ip='192.0.2.1'][ex:port='80']

/* instance-identifier for a leaf-list entry */
/ex:system/ex:services/ex:ssh/ex:cipher[.='blowfish-cbc']

/* instance-identifier for a list entry without keys */
/ex:stats/ex:port[3]
```

10. XPath Functions

This document defines two generic XPath functions and four YANG type-specific XPath functions. The function signatures are specified with the syntax used in [XPath].

10.1. Functions for Node Sets

10.1.1. current()

node-set current()

The function current() takes no input parameters, and returns a node set with the initial context node as its only member.

10.2. Functions for Strings

10.2.1. re-match()

boolean re-match(string subject, string pattern)

The re-match() function returns true if the "subject" string matches the regular expression "pattern"; otherwise it returns false.

The function "re-match" checks if a string matches a given regular expression. The regular expressions used are the XML Schema regular

expressions [XSD-TYPES]. Note that this includes implicit anchoring of the regular expression at the head and tail.

10.2.1.1. Usage Example

The expression:

```
re-match('1.22.333', '\d{1,3}\.\d{1,3}\.\d{1,3}')
```

returns true.

To count all logical interfaces called eth0.<number>, do:

```
count(/interface[re-match(name, 'eth0\.\d+')])
```

10.3. Functions for the YANG Types "leafref" and "instance-identifier"

10.3.1. deref()

```
node-set deref(node-set nodes)
```

The deref() function follows the reference defined by the first node in document order in the argument "nodes", and returns the nodes it refers to.

If the first argument node is of type instance-identifier, the function returns a node set that contains the single node that the instance identifier refers to, if it exists. If no such node exists, an empty node-set is returned.

If the first argument node is of type leafref, the function returns a node set that contains the nodes that the leafref refers to.

If the first argument node is of any other type, an empty node set is returned.

10.3.1.1. Usage Example

```
list interface {
    key name;
    leaf name { ... }
    leaf enabled {
        type boolean;
    }
    ...
}

leaf mgmt-interface {
    type leafref {
        path "/interface/name";
    }
    must 'deref(..)/../enabled = "true"' {
        error-message
            "The management interface cannot be disabled.";
    }
}
```

10.4. Functions for the YANG Type "identityref"

10.4.1. derived-from()

```
boolean derived-from(node-set nodes,
                     string module-name,
                     string identity-name)
```

The `derived-from()` function returns true if the first node in document order in the argument "nodes" is a node of type `identityref`, and its value is an identity that is derived from the identity "identity-name" defined in the YANG module "module-name"; otherwise it returns false.

10.4.2. derived-from-or-self()

```
boolean derived-from-or-self(node-set nodes,
                             string module-name,
                             string identity-name)
```

The `derived-from-or-self()` function returns true if the first node in document order in the argument "nodes" is a node of type `identityref`, and its value is an identity that is equal to or derived from the identity "identity-name" defined in the YANG module "module-name"; otherwise it returns false.

10.4.2.1. Usage Example

```
module example-interface {  
    ...  
  
    identity interface-type;  
  
    identity ethernet {  
        base interface-type;  
    }  
  
    identity fast-ethernet {  
        base ethernet;  
    }  
  
    identity gigabit-ethernet {  
        base ethernet;  
    }  
  
    list interface {  
        key name;  
        ...  
        leaf type {  
            type identityref {  
                base interface-type;  
            }  
        }  
        ...  
    }  
  
    augment "/interface" {  
        when 'derived-from(type,  
                                "example-interface",  
                                "ethernet")';  
        // ethernet-specific definitions here  
    }  
}
```

10.5. Functions for the YANG Type "enumeration"

10.5.1. enum-value()

```
number enum-value(node-set nodes)
```

The `enum-value()` function checks if the first node in document order in the argument "nodes" is a node of type enumeration, and returns the enum's integer value. If the "nodes" node set is empty, or if the first node in "nodes" is not of type enumeration, it returns NaN.

10.5.1.1. Usage Example

With this data model:

```
list alarm {  
  ...  
  leaf severity {  
    type enumeration {  
      enum cleared {  
        value 1;  
      }  
      enum indeterminate {  
        value 2;  
      }  
      enum minor {  
        value 3;  
      }  
      enum warning {  
        value 4;  
      }  
      enum major {  
        value 5;  
      }  
      enum critical {  
        value 6;  
      }  
    }  
  }  
}
```

the following XPath expression selects only alarms that are of severity "major" or higher:

```
/alarm[enum-value(severity) >= 5]
```

10.6. Functions for the YANG Type "bits"

10.6.1. bit-is-set()

```
boolean bit-is-set(node-set nodes, string bit-name)
```

The `bit-is-set()` function returns true if the first node in document order in the argument "nodes" is a node of type bits, and its value has the bit "'bit-name" set; otherwise it returns false.

10.6.1.1. Usage Example

If an interface has this leaf:

```
leaf flags {  
  type bits {  
    bit UP;  
    bit PROMISCUOUS  
    bit DISABLED;  
  }  
}
```

the following XPath expression can be used to select all interfaces with the UP flag set:

```
/interface[bit-is-set(flags, "UP")]
```

11. Updating a Module

As experience is gained with a module, it may be desirable to revise that module. However, changes are not allowed if they have any potential to cause interoperability problems between a client using an original specification and a server using an updated specification.

For any published change, a new "revision" statement (Section 7.1.9) MUST be included in front of the existing "revision" statements. If there are no existing "revision" statements, then one MUST be added to identify the new revision. Furthermore, any necessary changes MUST be applied to any meta-data statements, including the "organization" and "contact" statements (Section 7.1.7, Section 7.1.8).

Note that definitions contained in a module are available to be imported by any other module, and are referenced in "import" statements via the module name. Thus, a module name MUST NOT be changed. Furthermore, the "namespace" statement MUST NOT be changed, since all XML elements are qualified by the namespace.

Obsolete definitions MUST NOT be removed from modules since their identifiers may still be referenced by other modules.

A definition may be revised in any of the following ways:

- o An "enumeration" type may have new enums added, provided the old enums's values do not change.

- o A "bits" type may have new bits added, provided the old bit positions do not change.
- o A "range", "length", or "pattern" statement may expand the allowed value space.
- o A "default" statement may be added to a leaf that does not have a default value (either directly or indirectly through its type).
- o A "units" statement may be added.
- o A "reference" statement may be added or updated.
- o A "must" statement may be removed or its constraint relaxed.
- o A "mandatory" statement may be removed or changed from "true" to "false".
- o A "min-elements" statement may be removed, or changed to require fewer elements.
- o A "max-elements" statement may be removed, or changed to allow more elements.
- o A "description" statement may be added or clarified without changing the semantics of the definition.
- o A "base" statement may be added to an "identity" statement.
- o A "base" statement may be removed from an "identityref" type, provided there is at least one "base" statement left.
- o New typedefs, groupings, rpcs, notifications, extensions, features, and identities may be added.
- o New data definition statements may be added if they do not add mandatory nodes (Section 3.1) to existing nodes or at the top level in a module or submodule, or if they are conditionally dependent on a new feature (i.e., have an "if-feature" statement that refers to a new feature).
- o A new "case" statement may be added.
- o A node that represented state data may be changed to represent configuration, provided it is not mandatory (Section 3.1).
- o An "if-feature" statement may be removed, provided its node is not mandatory (Section 3.1).

- o A "status" statement may be added, or changed from "current" to "deprecated" or "obsolete", or from "deprecated" to "obsolete".
- o A "type" statement may be replaced with another "type" statement that does not change the syntax or semantics of the type. For example, an inline type definition may be replaced with a typedef, but an int8 type cannot be replaced by an int16, since the syntax would change.
- o Any set of data definition nodes may be replaced with another set of syntactically and semantically equivalent nodes. For example, a set of leafs may be replaced by a uses of a grouping with the same leafs.
- o A module may be split into a set of submodules, or a submodule may be removed, provided the definitions in the module do not change in any other way than allowed here.
- o The "prefix" statement may be changed, provided all local uses of the prefix also are changed.

Otherwise, if the semantics of any previous definition are changed (i.e., if a non-editorial change is made to any definition other than those specifically allowed above), then this **MUST** be achieved by a new definition with a new identifier.

In statements that have any data definition statements as substatements, those data definition substatements **MUST NOT** be reordered.

12. YIN

A YANG module can be translated into an alternative XML-based syntax called YIN. The translated module is called a YIN module. This section describes symmetric mapping rules between the two formats.

The YANG and YIN formats contain equivalent information using different notations. The YIN notation enables developers to represent YANG data models in XML and therefore use the rich set of XML-based tools for data filtering and validation, automated generation of code and documentation, and other tasks. Tools like XSLT or XML validators can be utilized.

The mapping between YANG and YIN does not modify the information content of the model. Comments and whitespace are not preserved.

12.1.1. Formal YIN Definition

There is a one-to-one correspondence between YANG keywords and YIN elements. The local name of a YIN element is identical to the corresponding YANG keyword. This means, in particular, that the document element (root) of a YIN document is always <module> or <submodule>.

YIN elements corresponding to the YANG keywords belong to the namespace whose associated URI is "urn:ietf:params:xml:ns:yang:yin:1".

YIN elements corresponding to extension keywords belong to the namespace of the YANG module where the extension keyword is declared via the "extension" statement.

The names of all YIN elements MUST be properly qualified with their namespaces specified above using the standard mechanisms of [XML-NAMES], i.e., "xmlns" and "xmlns:xxx" attributes.

The argument of a YANG statement is represented in YIN either as an XML attribute or a subelement of the keyword element. Table 1 defines the mapping for the set of YANG keywords. For extensions, the argument mapping is specified within the "extension" statement (see Section 7.18). The following rules hold for arguments:

- o If the argument is represented as an attribute, this attribute has no namespace.
- o If the argument is represented as an element, it is qualified by the same namespace as its parent keyword element.
- o If the argument is represented as an element, it MUST be the first child of the keyword element.

Substatements of a YANG statement are represented as (additional) children of the keyword element and their relative order MUST be the same as the order of substatements in YANG.

Comments in YANG MAY be mapped to XML comments.

| keyword | argument name | yin-element |
|----------|---------------|-------------|
| anyxml | name | false |
| argument | name | false |
| augment | target-node | false |
| base | name | false |

| | | |
|------------------|---------------|-------|
| belongs-to | module | false |
| bit | name | false |
| case | name | false |
| choice | name | false |
| config | value | false |
| contact | text | true |
| container | name | false |
| default | value | false |
| description | text | true |
| deviate | value | false |
| deviation | target-node | false |
| enum | name | false |
| error-app-tag | value | false |
| error-message | value | true |
| extension | name | false |
| feature | name | false |
| fraction-digits | value | false |
| grouping | name | false |
| identity | name | false |
| if-feature | name | false |
| import | module | false |
| include | module | false |
| input | <no argument> | n/a |
| key | value | false |
| leaf | name | false |
| leaf-list | name | false |
| length | value | false |
| list | name | false |
| mandatory | value | false |
| max-elements | value | false |
| min-elements | value | false |
| module | name | false |
| must | condition | false |
| namespace | uri | false |
| notification | name | false |
| ordered-by | value | false |
| organization | text | true |
| output | <no argument> | n/a |
| path | value | false |
| pattern | value | false |
| position | value | false |
| prefix | value | false |
| presence | value | false |
| range | value | false |
| reference | text | true |
| refine | target-node | false |
| require-instance | value | false |
| revision | date | false |

| | | |
|---------------|-----------|-------|
| revision-date | date | false |
| rpc | name | false |
| status | value | false |
| submodule | name | false |
| type | name | false |
| typedef | name | false |
| unique | tag | false |
| units | name | false |
| uses | name | false |
| value | value | false |
| when | condition | false |
| yang-version | value | false |
| yin-element | value | false |

Table 1: Mapping of arguments of the YANG statements.

12.1.1.1. Usage Example

The following YANG module:

```

module acme-foo {
  yang-version 1.1;
  namespace "http://acme.example.com/foo";
  prefix "acfoo";

  import my-extensions {
    prefix "myext";
  }

  list interface {
    key "name";
    leaf name {
      type string;
    }

    leaf mtu {
      type uint32;
      description "The MTU of the interface.";
      myext:c-define "MY_MTU";
    }
  }
}

```

where the extension "c-define" is defined in Section 7.18.3, is translated into the following YIN:


```

<module name="acme-foo"
  xmlns="urn:ietf:params:xml:ns:yang:1"
  xmlns:acfoo="http://acme.example.com/foo"
  xmlns:myext="http://example.com/my-extensions">

  <namespace uri="http://acme.example.com/foo"/>
  <prefix value="acfoo"/>

  <import module="my-extensions">
    <prefix value="myext"/>
  </import>

  <list name="interface">
    <key value="name"/>
    <leaf name="name">
      <type name="string"/>
    </leaf>
    <leaf name="mtu">
      <type name="uint32"/>
      <description>
        <text>The MTU of the interface.</text>
      </description>
      <myext:c-define name="MY_MTU"/>
    </leaf>
  </list>
</module>

```

13. YANG ABNF Grammar

In YANG, almost all statements are unordered. The ABNF grammar [RFC5234] [RFC7405] defines the canonical order. To improve module readability, it is RECOMMENDED that clauses be entered in this order.

Within the ABNF grammar, unordered statements are marked with comments.

This grammar assumes that the scanner replaces YANG comments with a single space character.

<CODE BEGINS> file "yang.abnf"

```

module-stmt      = optsep module-keyword sep identifier-arg-str
                  optsep
                  "{" stmtsep
                    module-header-stmts
                    linkage-stmts
                    meta-stmts
                    revision-stmts

```

```
        body-stmts
    "}" optsep

submodule-stmt    = optsep submodule-keyword sep identifier-arg-str
                  optsep
                  "{" stmtsep
                    submodule-header-stmts
                    linkage-stmts
                    meta-stmts
                    revision-stmts
                    body-stmts
                  "}" optsep

module-header-stmts = ;; these stmts can appear in any order
                      yang-version-stmt
                      namespace-stmt
                      prefix-stmt

submodule-header-stmts =
                      ;; these stmts can appear in any order
                      yang-version-stmt
                      belongs-to-stmt

meta-stmts        = ;; these stmts can appear in any order
                      [organization-stmt]
                      [contact-stmt]
                      [description-stmt]
                      [reference-stmt]

linkage-stmts     = ;; these stmts can appear in any order
                      *import-stmt
                      *include-stmt

revision-stmts    = *revision-stmt

body-stmts        = *(extension-stmt /
                      feature-stmt /
                      identity-stmt /
                      typedef-stmt /
                      grouping-stmt /
                      data-def-stmt /
                      augment-stmt /
                      rpc-stmt /
                      notification-stmt /
                      deviation-stmt)

data-def-stmt     = container-stmt /
                      leaf-stmt /
```

```
leaf-list-stmt /
list-stmt /
choice-stmt /
anyxml-stmt /
uses-stmt

yang-version-stmt    = yang-version-keyword sep yang-version-arg-str
                        stmtend

yang-version-arg-str = < a string that matches the rule >
                        < yang-version-arg >

yang-version-arg      = "1.1"

import-stmt           = import-keyword sep identifier-arg-str optsep
                        "{" stmtsep
                        prefix-stmt
                        [revision-date-stmt]
                        "}" stmtsep

include-stmt          = include-keyword sep identifier-arg-str optsep
                        (";" /
                        "{" stmtsep
                        [revision-date-stmt]
                        "}") stmtsep

namespace-stmt        = namespace-keyword sep uri-str stmtend

uri-str               = < a string that matches the rule >
                        < URI in RFC 3986 >

prefix-stmt           = prefix-keyword sep prefix-arg-str stmtend

belongs-to-stmt       = belongs-to-keyword sep identifier-arg-str
                        optsep
                        "{" stmtsep
                        prefix-stmt
                        "}" stmtsep

organization-stmt     = organization-keyword sep string stmtend

contact-stmt          = contact-keyword sep string stmtend

description-stmt      = description-keyword sep string stmtend

reference-stmt        = reference-keyword sep string stmtend

units-stmt            = units-keyword sep string stmtend
```

```
revision-stmt      = revision-keyword sep revision-date optsep
                    ( ";" /
                      "{" stmtsep
                        ;; these stmts can appear in any order
                        [description-stmt]
                        [reference-stmt]
                      "}") stmtsep

revision-date      = date-arg-str

revision-date-stmt = revision-date-keyword sep revision-date stmtend

extension-stmt     = extension-keyword sep identifier-arg-str optsep
                    ( ";" /
                      "{" stmtsep
                        ;; these stmts can appear in any order
                        [argument-stmt]
                        [status-stmt]
                        [description-stmt]
                        [reference-stmt]
                      "}") stmtsep

argument-stmt      = argument-keyword sep identifier-arg-str optsep
                    ( ";" /
                      "{" stmtsep
                        [yin-element-stmt]
                      "}") stmtsep

yin-element-stmt   = yin-element-keyword sep yin-element-arg-str
                    stmtend

yin-element-arg-str = < a string that matches the rule >
                    < yin-element-arg >

yin-element-arg     = true-keyword / false-keyword

identity-stmt      = identity-keyword sep identifier-arg-str optsep
                    ( ";" /
                      "{" stmtsep
                        ;; these stmts can appear in any order
                        *if-feature-stmt
                        *base-stmt
                        [status-stmt]
                        [description-stmt]
                        [reference-stmt]
                      "}") stmtsep

base-stmt          = base-keyword sep identifier-ref-arg-str
```

```
stmtend

feature-stmt      = feature-keyword sep identifier-arg-str optsep
                   ( ";" /
                     "{" stmtsep
                       ;; these stmts can appear in any order
                       *if-feature-stmt
                       [status-stmt]
                       [description-stmt]
                       [reference-stmt]
                     "}") stmtsep

if-feature-stmt   = if-feature-keyword sep if-feature-expr-str
                   stmtend

if-feature-expr-str = < a string that matches the rule >
                     < if-feature-expr >

if-feature-expr    = "(" if-feature-expr ")" /
                     if-feature-expr sep boolean-operator sep
                       if-feature-expr /
                     not-keyword sep if-feature-expr /
                     identifier-ref-arg

boolean-operator   = and-keyword / or-keyword

typedef-stmt      = typedef-keyword sep identifier-arg-str optsep
                   "{" stmtsep
                     ;; these stmts can appear in any order
                     type-stmt
                     [units-stmt]
                     [default-stmt]
                     [status-stmt]
                     [description-stmt]
                     [reference-stmt]
                   "}" stmtsep

type-stmt         = type-keyword sep identifier-ref-arg-str optsep
                   ( ";" /
                     "{" stmtsep
                       [type-body-stmts]
                     "}") stmtsep

type-body-stmts   = numerical-restrictions /
                   decimal64-specification /
                   string-restrictions /
                   enum-specification /
                   leafref-specification /
```

```
identityref-specification /
instance-identifier-specification /
bits-specification /
union-specification /
binary-specification

numerical-restrictions = range-stmt

range-stmt              = range-keyword sep range-arg-str optsep
                        ( ";" /
                          "{" stmtsep
                            ;; these stmts can appear in any order
                            [error-message-stmt]
                            [error-app-tag-stmt]
                            [description-stmt]
                            [reference-stmt]
                          "}") stmtsep

decimal64-specification = ;; these stmts can appear in any order
                        fraction-digits-stmt
                        [range-stmt]

fraction-digits-stmt = fraction-digits-keyword sep
                      fraction-digits-arg-str stmtend

fraction-digits-arg-str = < a string that matches the rule >
                       < fraction-digits-arg >

fraction-digits-arg = ("1" ["0" / "1" / "2" / "3" / "4" /
                          "5" / "6" / "7" / "8"])
                    / "2" / "3" / "4" / "5" / "6" / "7" / "8" / "9"

string-restrictions = ;; these stmts can appear in any order
                    [length-stmt]
                    *pattern-stmt

length-stmt            = length-keyword sep length-arg-str optsep
                        ( ";" /
                          "{" stmtsep
                            ;; these stmts can appear in any order
                            [error-message-stmt]
                            [error-app-tag-stmt]
                            [description-stmt]
                            [reference-stmt]
                          "}") stmtsep

pattern-stmt           = pattern-keyword sep string optsep
                        ( ";" /
```

```
        "{" stmtsep
          ;; these stmts can appear in any order
          [modifier-stmt]
          [error-message-stmt]
          [error-app-tag-stmt]
          [description-stmt]
          [reference-stmt]
        "}") stmtsep

modifier-stmt      = modifier-keyword sep modifier-arg-str stmtend

modifier-arg-str   = < a string that matches the rule >
                    < modifier-arg >

modifier-arg       = invert-match-keyword

default-stmt       = default-keyword sep string stmtend

enum-specification = 1*enum-stmt

enum-stmt          = enum-keyword sep string optsep
                    ( ";" /
                    "{" stmtsep
                      ;; these stmts can appear in any order
                      *if-feature-stmt
                      [value-stmt]
                      [status-stmt]
                      [description-stmt]
                      [reference-stmt]
                    "}") stmtsep

leafref-specification =
    ;; these stmts can appear in any order
    path-stmt
    [require-instance-stmt]

path-stmt          = path-keyword sep path-arg-str stmtend

require-instance-stmt = require-instance-keyword sep
                        require-instance-arg-str stmtend

require-instance-arg-str = < a string that matches the rule >
                           < require-instance-arg >

require-instance-arg = true-keyword / false-keyword

instance-identifier-specification =
```

```
[require-instance-stmt]

identityref-specification =
    1*base-stmt

union-specification = 1*type-stmt

binary-specification = [length-stmt]

bits-specification  = 1*bit-stmt

bit-stmt            = bit-keyword sep identifier-arg-str optsep
                      ( ";" /
                        "{" stmtsep
                          ;; these stmts can appear in any order
                          *if-feature-stmt
                          [position-stmt]
                          [status-stmt]
                          [description-stmt]
                          [reference-stmt]
                        "}") stmtsep

position-stmt        = position-keyword sep
                      position-value-arg-str stmtend

position-value-arg-str = < a string that matches the rule >
                      < position-value-arg >

position-value-arg    = non-negative-integer-value

status-stmt           = status-keyword sep status-arg-str stmtend

status-arg-str        = < a string that matches the rule >
                      < status-arg >

status-arg            = current-keyword /
                      obsolete-keyword /
                      deprecated-keyword

config-stmt           = config-keyword sep
                      config-arg-str stmtend

config-arg-str        = < a string that matches the rule >
                      < config-arg >

config-arg            = true-keyword / false-keyword

mandatory-stmt        = mandatory-keyword sep
```



```
mandatory-arg-str stmtend

mandatory-arg-str = < a string that matches the rule >
                  < mandatory-arg >

mandatory-arg      = true-keyword / false-keyword

presence-stmt      = presence-keyword sep string stmtend

ordered-by-stmt     = ordered-by-keyword sep
                  ordered-by-arg-str stmtend

ordered-by-arg-str = < a string that matches the rule >
                  < ordered-by-arg >

ordered-by-arg      = user-keyword / system-keyword

must-stmt           = must-keyword sep string optsep
                  ( ";" /
                    "{" stmtsep
                      ;; these stmts can appear in any order
                      [error-message-stmt]
                      [error-app-tag-stmt]
                      [description-stmt]
                      [reference-stmt]
                    "}") stmtsep

error-message-stmt  = error-message-keyword sep string stmtend

error-app-tag-stmt  = error-app-tag-keyword sep string stmtend

min-elements-stmt   = min-elements-keyword sep
                  min-value-arg-str stmtend

min-value-arg-str   = < a string that matches the rule >
                  < min-value-arg >

min-value-arg        = non-negative-integer-value

max-elements-stmt    = max-elements-keyword sep
                  max-value-arg-str stmtend

max-value-arg-str    = < a string that matches the rule >
                  < max-value-arg >

max-value-arg        = unbounded-keyword /
                  positive-integer-value
```

```
value-stmt          = value-keyword sep integer-value-str stmtend

integer-value-str    = < a string that matches the rule >
                      < integer-value >

grouping-stmt       = grouping-keyword sep identifier-arg-str optsep
                      ( ";" /
                        "{" stmtsep
                          ;; these stmts can appear in any order
                          [status-stmt]
                          [description-stmt]
                          [reference-stmt]
                          *(typedef-stmt / grouping-stmt)
                          *data-def-stmt
                          *action-stmt
                        "}") stmtsep

container-stmt       = container-keyword sep identifier-arg-str optsep
                      ( ";" /
                        "{" stmtsep
                          ;; these stmts can appear in any order
                          [when-stmt]
                          *if-feature-stmt
                          *must-stmt
                          [presence-stmt]
                          [config-stmt]
                          [status-stmt]
                          [description-stmt]
                          [reference-stmt]
                          *(typedef-stmt / grouping-stmt)
                          *data-def-stmt
                          *action-stmt
                        "}") stmtsep

leaf-stmt            = leaf-keyword sep identifier-arg-str optsep
                      "{" stmtsep
                        ;; these stmts can appear in any order
                        [when-stmt]
                        *if-feature-stmt
                        type-stmt
                        [units-stmt]
                        *must-stmt
                        [default-stmt]
                        [config-stmt]
                        [mandatory-stmt]
                        [status-stmt]
                        [description-stmt]
                        [reference-stmt]
```

```
    "}" stmtsep

leaf-list-stmt      = leaf-list-keyword sep identifier-arg-str optsep
    "{" stmtsep
    ;; these stmts can appear in any order
    [when-stmt]
    *if-feature-stmt
    type-stmt stmtsep
    [units-stmt]
    *must-stmt
    *default-stmt
    [config-stmt]
    [min-elements-stmt]
    [max-elements-stmt]
    [ordered-by-stmt]
    [status-stmt]
    [description-stmt]
    [reference-stmt]
    "}" stmtsep

list-stmt           = list-keyword sep identifier-arg-str optsep
    "{" stmtsep
    ;; these stmts can appear in any order
    [when-stmt]
    *if-feature-stmt
    *must-stmt
    [key-stmt]
    *unique-stmt
    [config-stmt]
    [min-elements-stmt]
    [max-elements-stmt]
    [ordered-by-stmt]
    [status-stmt]
    [description-stmt]
    [reference-stmt]
    *(typedef-stmt / grouping-stmt)
    1*data-def-stmt
    *action-stmt
    "}" stmtsep

key-stmt            = key-keyword sep key-arg-str stmtend

key-arg-str         = < a string that matches the rule >
    < key-arg >

key-arg             = node-identifier *(sep node-identifier)

unique-stmt         = unique-keyword sep unique-arg-str stmtend
```

```
unique-arg-str      = < a string that matches the rule >
                     < unique-arg >

unique-arg           = descendant-schema-nodeid
                     *(sep descendant-schema-nodeid)

choice-stmt          = choice-keyword sep identifier-arg-str optsep
                     (";" /
                      "{" stmtsep
                      ;; these stmts can appear in any order
                      [when-stmt]
                      *if-feature-stmt
                      [default-stmt]
                      [config-stmt]
                      [mandatory-stmt]
                      [status-stmt]
                      [description-stmt]
                      [reference-stmt]
                      *(short-case-stmt / case-stmt)
                      "}") stmtsep

short-case-stmt      = choice-stmt /
                     container-stmt /
                     leaf-stmt /
                     leaf-list-stmt /
                     list-stmt /
                     anyxml-stmt

case-stmt             = case-keyword sep identifier-arg-str optsep
                     (";" /
                      "{" stmtsep
                      ;; these stmts can appear in any order
                      [when-stmt]
                      *if-feature-stmt
                      [status-stmt]
                      [description-stmt]
                      [reference-stmt]
                      *data-def-stmt
                      "}") stmtsep

anyxml-stmt          = anyxml-keyword sep identifier-arg-str optsep
                     (";" /
                      "{" stmtsep
                      ;; these stmts can appear in any order
                      [when-stmt]
                      *if-feature-stmt
                      *must-stmt
                      [config-stmt]
```

```

        [mandatory-stmt]
        [status-stmt]
        [description-stmt]
        [reference-stmt]
    "}" ) stmtsep

uses-stmt      = uses-keyword sep identifier-ref-arg-str optsep
                 ( ";" /
                 "{" stmtsep
                 ;; these stmts can appear in any order
                 [when-stmt]
                 *if-feature-stmt
                 [status-stmt]
                 [description-stmt]
                 [reference-stmt]
                 *refine-stmt
                 *uses-augment-stmt
                 "}" ) stmtsep

refine-stmt    = refine-keyword sep refine-arg-str optsep
                 "{" stmtsep
                 ;; these stmts can appear in any order
                 *if-feature-stmt
                 *must-stmt
                 [presence-stmt]
                 [default-stmt]
                 [config-stmt]
                 [mandatory-stmt]
                 [min-elements-stmt]
                 [max-elements-stmt]
                 [description-stmt]
                 [reference-stmt]
                 "}" stmtsep

refine-arg-str = < a string that matches the rule >
                 < refine-arg >

refine-arg     = descendant-schema-nodeid

uses-augment-stmt = augment-keyword sep uses-augment-arg-str optsep
                  "{" stmtsep
                  ;; these stmts can appear in any order
                  [when-stmt]
                  *if-feature-stmt
                  [status-stmt]
                  [description-stmt]
                  [reference-stmt]
                  1*(data-def-stmt / case-stmt / action-stmt)

```

```
        "}" stmtsep

uses-augment-arg-str = < a string that matches the rule >
                      < uses-augment-arg >

uses-augment-arg      = descendant-schema-nodeid

augment-stmt          = augment-keyword sep augment-arg-str optsep
                        "{" stmtsep
                        ;; these stmts can appear in any order
                        [when-stmt]
                        *if-feature-stmt
                        [status-stmt]
                        [description-stmt]
                        [reference-stmt]
                        1*(data-def-stmt / case-stmt / action-stmt)
                        "}" stmtsep

augment-arg-str        = < a string that matches the rule >
                        < augment-arg >

augment-arg            = absolute-schema-nodeid

when-stmt              = when-keyword sep string optsep
                        (";" /
                        "{" stmtsep
                        ;; these stmts can appear in any order
                        [description-stmt]
                        [reference-stmt]
                        "}") stmtsep

rpc-stmt               = rpc-keyword sep identifier-arg-str optsep
                        (";" /
                        "{" stmtsep
                        ;; these stmts can appear in any order
                        *if-feature-stmt
                        [status-stmt]
                        [description-stmt]
                        [reference-stmt]
                        *(typedef-stmt / grouping-stmt)
                        [input-stmt]
                        [output-stmt]
                        "}") stmtsep

action-stmt            = action-keyword sep identifier-arg-str optsep
                        (";" /
                        "{" stmtsep
                        ;; these stmts can appear in any order
```

```

        *if-feature-stmt
        [status-stmt]
        [description-stmt]
        [reference-stmt]
        *(typedef-stmt / grouping-stmt)
        [input-stmt]
        [output-stmt]
    "}") stmtsep

input-stmt      = input-keyword optsep
                  "{" stmtsep
                  ;; these stmts can appear in any order
                  *must-stmt
                  *(typedef-stmt / grouping-stmt)
                  1*data-def-stmt
                  "}" stmtsep

output-stmt     = output-keyword optsep
                  "{" stmtsep
                  ;; these stmts can appear in any order
                  *must-stmt
                  *(typedef-stmt / grouping-stmt)
                  1*data-def-stmt
                  "}" stmtsep

notification-stmt = notification-keyword sep
                  identifier-arg-str optsep
                  (";" /
                  "{" stmtsep
                  ;; these stmts can appear in any order
                  *if-feature-stmt
                  *must-stmt
                  [status-stmt]
                  [description-stmt]
                  [reference-stmt]
                  *(typedef-stmt / grouping-stmt)
                  *data-def-stmt
                  "}") stmtsep

deviation-stmt  = deviation-keyword sep
                  deviation-arg-str optsep
                  "{" stmtsep
                  ;; these stmts can appear in any order
                  [description-stmt]
                  [reference-stmt]
                  (deviate-not-supported-stmt /
                  1*(deviate-add-stmt /
                     deviate-replace-stmt /

```

```
                                deviate-delete-stmt))
                                "}" stmtsep

deviation-arg-str    = < a string that matches the rule >
                        < deviation-arg >

deviation-arg        = absolute-schema-nodeid

deviate-not-supported-stmt =
    deviate-keyword sep
    not-supported-keyword-str stmtend

deviate-add-stmt     = deviate-keyword sep add-keyword-str optsep
                        ( ";" /
                        "{" stmtsep
                        ;; these stmts can appear in any order
                        [units-stmt]
                        *must-stmt
                        *unique-stmt
                        [default-stmt]
                        [config-stmt]
                        [mandatory-stmt]
                        [min-elements-stmt]
                        [max-elements-stmt]
                        "}") stmtsep

deviate-delete-stmt = deviate-keyword sep delete-keyword-str optsep
                        ( ";" /
                        "{" stmtsep
                        ;; these stmts can appear in any order
                        [units-stmt]
                        *must-stmt
                        *unique-stmt
                        [default-stmt]
                        "}") stmtsep

deviate-replace-stmt = deviate-keyword sep replace-keyword-str optsep
                        ( ";" /
                        "{" stmtsep
                        ;; these stmts can appear in any order
                        [type-stmt]
                        [units-stmt]
                        [default-stmt]
                        [config-stmt]
                        [mandatory-stmt]
                        [min-elements-stmt]
                        [max-elements-stmt]
                        "}") stmtsep
```



```
not-supported-keyword-str = < a string that matches the rule >
                           < not-supported-keyword >

add-keyword-str           = < a string that matches the rule >
                           < add-keyword >

delete-keyword-str       = < a string that matches the rule >
                           < delete-keyword >

replace-keyword-str      = < a string that matches the rule >
                           < replace-keyword >

;; represents the usage of an extension statement
unknown-statement        = prefix ":" identifier [sep string] optsep
                           (";" /
                            "{" optsep
                              *((yang-stmt / unknown-statement) optsep)
                              "}") stmtsep

yang-stmt                 = action-stmt /
                           anyxml-stmt /
                           argument-stmt /
                           augment-stmt /
                           base-stmt /
                           belongs-to-stmt /
                           bit-stmt /
                           case-stmt /
                           choice-stmt /
                           config-stmt /
                           contact-stmt /
                           container-stmt /
                           default-stmt /
                           description-stmt /
                           deviate-add-stmt /
                           deviate-delete-stmt /
                           deviate-not-supported-stmt /
                           deviate-replace-stmt /
                           deviation-stmt /
                           enum-stmt /
                           error-app-tag-stmt /
                           error-message-stmt /
                           extension-stmt /
                           feature-stmt /
                           fraction-digits-stmt /
                           grouping-stmt /
                           identity-stmt /
                           if-feature-stmt /
                           import-stmt /
```

```
include-stmt /
input-stmt /
key-stmt /
leaf-list-stmt /
leaf-stmt /
length-stmt /
list-stmt /
mandatory-stmt /
max-elements-stmt /
min-elements-stmt /
modifier-stmt /
module-stmt /
must-stmt /
namespace-stmt /
notification-stmt /
ordered-by-stmt /
organization-stmt /
output-stmt /
path-stmt /
pattern-stmt /
position-stmt /
prefix-stmt /
presence-stmt /
range-stmt /
reference-stmt /
refine-stmt /
require-instance-stmt /
revision-date-stmt /
revision-stmt /
rpc-stmt /
status-stmt /
submodule-stmt /
typedef-stmt /
type-stmt /
unique-stmt /
units-stmt /
uses-augment-stmt /
uses-stmt /
value-stmt /
when-stmt /
yang-version-stmt /
yin-element-stmt
```

;; Ranges

```
range-arg-str      = < a string that matches the rule >
                   < range-arg >
```

```
range-arg          = range-part *(optsep "|" optsep range-part)
range-part         = range-boundary
                    [optsep ".." optsep range-boundary]
range-boundary     = min-keyword / max-keyword /
                    integer-value / decimal-value

;; Lengths
length-arg-str     = < a string that matches the rule >
                    < length-arg >
length-arg         = length-part *(optsep "|" optsep length-part)
length-part        = length-boundary
                    [optsep ".." optsep length-boundary]
length-boundary    = min-keyword / max-keyword /
                    non-negative-integer-value

;; Date
date-arg-str       = < a string that matches the rule >
                    < date-arg >
date-arg           = 4DIGIT "-" 2DIGIT "-" 2DIGIT

;; Schema Node Identifiers
schema-nodeid      = absolute-schema-nodeid /
                    descendant-schema-nodeid
absolute-schema-nodeid = 1*("/") node-identifier)
descendant-schema-nodeid =
    node-identifier
    [absolute-schema-nodeid]
node-identifier     = [prefix ":" ] identifier

;; Instance Identifiers
instance-identifier = 1*("/") (node-identifier *predicate))
predicate           = "[" *WSP (predicate-expr / pos) *WSP "]"
```

```
predicate-expr      = (node-identifier / ".") *WSP "=" *WSP
                      ((DQUOTE string DQUOTE) /
                       (SQUOTE string SQUOTE))

pos                  = non-negative-integer-value

;; leafref path

path-arg-str         = < a string that matches the rule >
                      < path-arg >

path-arg             = absolute-path / relative-path

absolute-path        = 1*("/") (node-identifier *path-predicate))

relative-path        = 1*(".." "/") descendant-path

descendant-path      = node-identifier
                      [*path-predicate absolute-path]

path-predicate       = "[" *WSP path-equality-expr *WSP "]"

path-equality-expr   = node-identifier *WSP "=" *WSP path-key-expr

path-key-expr        = current-function-invocation *WSP "/" *WSP
                      rel-path-keyexpr

rel-path-keyexpr     = 1*(".." *WSP "/" *WSP)
                      *(node-identifier *WSP "/" *WSP)
                      node-identifier

;;; Keywords, using RFC 7405 syntax for case-sensitive strings

;; statement keywords
action-keyword       = %s"action"
anyxml-keyword       = %s"anyxml"
argument-keyword     = %s"argument"
augment-keyword      = %s"augment"
base-keyword         = %s"base"
belongs-to-keyword   = %s"belongs-to"
bit-keyword          = %s"bit"
case-keyword         = %s"case"
choice-keyword       = %s"choice"
config-keyword       = %s"config"
contact-keyword      = %s"contact"
container-keyword    = %s"container"
default-keyword      = %s"default"
```

description-keyword = %s"description"
enum-keyword = %s"enum"
error-app-tag-keyword = %s"error-app-tag"
error-message-keyword = %s"error-message"
extension-keyword = %s"extension"
deviation-keyword = %s"deviation"
deviate-keyword = %s"deviate"
feature-keyword = %s"feature"
fraction-digits-keyword = %s"fraction-digits"
grouping-keyword = %s"grouping"
identity-keyword = %s"identity"
if-feature-keyword = %s"if-feature"
import-keyword = %s"import"
include-keyword = %s"include"
input-keyword = %s"input"
key-keyword = %s"key"
leaf-keyword = %s"leaf"
leaf-list-keyword = %s"leaf-list"
length-keyword = %s"length"
list-keyword = %s"list"
mandatory-keyword = %s"mandatory"
max-elements-keyword = %s"max-elements"
min-elements-keyword = %s"min-elements"
modifier-keyword = %s"modifier"
module-keyword = %s"module"
must-keyword = %s"must"
namespace-keyword = %s"namespace"
notification-keyword = %s"notification"
ordered-by-keyword = %s"ordered-by"
organization-keyword = %s"organization"
output-keyword = %s"output"
path-keyword = %s"path"
pattern-keyword = %s"pattern"
position-keyword = %s"position"
prefix-keyword = %s"prefix"
presence-keyword = %s"presence"
range-keyword = %s"range"
reference-keyword = %s"reference"
refine-keyword = %s"refine"
require-instance-keyword = %s"require-instance"
revision-keyword = %s"revision"
revision-date-keyword = %s"revision-date"
rpc-keyword = %s"rpc"
status-keyword = %s"status"
submodule-keyword = %s"submodule"
type-keyword = %s"type"
typedef-keyword = %s"typedef"
unique-keyword = %s"unique"

```

units-keyword      = %s"units"
uses-keyword       = %s"uses"
value-keyword      = %s"value"
when-keyword       = %s"when"
yang-version-keyword= %s"yang-version"
yin-element-keyword= %s"yin-element"

;; other keywords

add-keyword        = %s"add"
current-keyword    = %s"current"
delete-keyword     = %s"delete"
deprecated-keyword = %s"deprecated"
false-keyword      = %s"false"
invert-match-keyword = %s"invert-match"
max-keyword        = %s"max"
min-keyword        = %s"min"
not-supported-keyword = %s"not-supported"
obsolete-keyword   = %s"obsolete"
replace-keyword    = %s"replace"
system-keyword     = %s"system"
true-keyword       = %s"true"
unbounded-keyword  = %s"unbounded"
user-keyword       = %s"user"

and-keyword        = %s"and"
or-keyword         = %s"or"
not-keyword        = %s"not"

current-function-invocation = current-keyword *WSP "(" *WSP ")"

;;; Basic Rules

prefix-arg-str      = < a string that matches the rule >
                    < prefix-arg >

prefix-arg          = prefix

prefix              = identifier

identifier-arg-str   = < a string that matches the rule >
                    < identifier-arg >

identifier-arg       = identifier

;; An identifier MUST NOT start with (('X'|'x') ('M'|'m') ('L'|'l'))
identifier           = (ALPHA / "_")
                    *(ALPHA / DIGIT / "_" / "-" / ".")

```

```

identifier-ref-arg-str = < a string that matches the rule >
                        < identifier-ref-arg >

identifier-ref-arg      = identifier-ref

identifier-ref          = [prefix ":" ] identifier

string                 = < an unquoted string as returned by >
                        < the scanner, that matches the rule >
                        < yang-string >

yang-string            = *yang-char

;; any Unicode character including tab, carriage return, and line
;; feed, but excluding the other C0 control characters, the surrogate
;; blocks, and the noncharacters.
yang-char = %x9 / %xA / %xD / %x20-D7FF /
            ; exclude surrogate blocks %xD800-DFFF
            %xE000-FDCF /      ; exclude noncharacters %xFDD0-FDEF
            %xFDF0-FFFD /      ; exclude noncharacters %xFFFFE-FFFF
            %x10000-1FFFD /     ; exclude noncharacters %x1FFFE-1FFFF
            %x20000-2FFFD /     ; exclude noncharacters %x2FFFE-2FFFF
            %x30000-3FFFD /     ; exclude noncharacters %x3FFFE-3FFFF
            %x40000-4FFFD /     ; exclude noncharacters %x4FFFE-4FFFF
            %x50000-5FFFD /     ; exclude noncharacters %x5FFFE-5FFFF
            %x60000-6FFFD /     ; exclude noncharacters %x6FFFE-6FFFF
            %x70000-7FFFD /     ; exclude noncharacters %x7FFFE-7FFFF
            %x80000-8FFFD /     ; exclude noncharacters %x8FFFE-8FFFF
            %x90000-9FFFD /     ; exclude noncharacters %x9FFFE-9FFFF
            %xA0000-AFFFD /     ; exclude noncharacters %xAFFFE-AFFFF
            %xB0000-BFFFD /     ; exclude noncharacters %xBFFFE-BFFFF
            %xC0000-CFFFD /     ; exclude noncharacters %xCFFFE-CFFFF
            %xD0000-DFFFD /     ; exclude noncharacters %xDFFFE-DFFFF
            %xE0000-EFFFD /     ; exclude noncharacters %xEFFFE-EFFFF
            %xF0000-FFFFD /     ; exclude noncharacters %xFFFFE-FFFFF
            %x100000-10FFFD ; exclude noncharacters %x10FFFE-10FFFF

integer-value          = ("-" non-negative-integer-value) /
                        non-negative-integer-value

non-negative-integer-value = "0" / positive-integer-value

positive-integer-value = (non-zero-digit *DIGIT)

zero-integer-value     = 1*DIGIT

stmtend                = optsep (";" / "{" stmtsep "}") stmtsep

```

```
sep                = 1*(WSP / line-break)
                   ; unconditional separator

optsep            = *(WSP / line-break)

stmtsep           = *(WSP / line-break / unknown-statement)

line-break        = CRLF / LF

non-zero-digit    = %x31-39

decimal-value     = integer-value ( "." zero-integer-value )

SQUOTE           = %x27
                   ; ' (Single Quote)

;;; RFC 5234 core rules.

ALPHA             = %x41-5A / %x61-7A
                   ; A-Z / a-z

CR               = %x0D
                   ; carriage return

CRLF             = CR LF
                   ; Internet standard new line

DIGIT            = %x30-39
                   ; 0-9

DQUOTE          = %x22
                   ; double quote

HEXDIG           = DIGIT /
                   %x61 / %x62 / %x63 / %x64 / %x65 / %x66
                   ; only lower-case a..f

HTAB             = %x09
                   ; horizontal tab

LF              = %x0A
                   ; linefeed

SP              = %x20
                   ; space

VCHAR            = %x21-7E
                   ; visible (printing) characters
```



```
WSP                = SP / HTAB
                   ; whitespace
```

```
<CODE ENDS>
```

14. Error Responses for YANG Related Errors

A number of NETCONF error responses are defined for error cases related to the data-model handling. If the relevant YANG statement has an "error-app-tag" substatement, that overrides the default value specified below.

14.1. Error Message for Data That Violates a unique Statement

If a NETCONF operation would result in configuration data where a unique constraint is invalidated, the following error is returned:

```
error-tag:          operation-failed
error-app-tag:      data-not-unique
error-info:         <non-unique>: Contains an instance identifier that
                    points to a leaf that invalidates the unique
                    constraint. This element is present once for each
                    non-unique leaf.
```

The <non-unique> element is in the YANG namespace ("urn:ietf:params:xml:ns:yang:1").

14.2. Error Message for Data That Violates a max-elements Statement

If a NETCONF operation would result in configuration data where a list or a leaf-list would have too many entries the following error is returned:

```
error-tag:          operation-failed
error-app-tag:      too-many-elements
```

This error is returned once, with the error-path identifying the list node, even if there are more than one extra child present.

14.3. Error Message for Data That Violates a min-elements Statement

If a NETCONF operation would result in configuration data where a list or a leaf-list would have too few entries the following error is returned:

```
error-tag:          operation-failed
error-app-tag:      too-few-elements
```

This error is returned once, with the error-path identifying the list node, even if there are more than one child missing.

14.4. Error Message for Data That Violates a must Statement

If a NETCONF operation would result in configuration data where the restrictions imposed by a "must" statement is violated the following error is returned, unless a specific "error-app-tag" substatement is present for the "must" statement.

```
error-tag:      operation-failed
error-app-tag:  must-violation
```

14.5. Error Message for Data That Violates a require-instance Statement

If a NETCONF operation would result in configuration data where a leaf of type "instance-identifier" marked with require-instance "true" refers to a non-existing instance, the following error is returned:

```
error-tag:      data-missing
error-app-tag:  instance-required
error-path:     Path to the instance-identifier leaf.
```

14.6. Error Message for Data That Does Not Match a leafref Type

If a NETCONF operation would result in configuration data where a leaf of type "leafref" refers to a non-existing instance, the following error is returned:

```
error-tag:      data-missing
error-app-tag:  instance-required
error-path:     Path to the leafref leaf.
```

14.7. Error Message for Data That Violates a mandatory choice Statement

If a NETCONF operation would result in configuration data where no nodes exists in a mandatory choice, the following error is returned:

```
error-tag:      data-missing
error-app-tag:  missing-choice
error-path:     Path to the element with the missing choice.
error-info:     <missing-choice>: Contains the name of the missing
                mandatory choice.
```

The <missing-choice> element is in the YANG namespace ("urn:ietf:params:xml:ns:yang:1").

14.8. Error Message for the "insert" Operation

If the "insert" and "key" or "value" attributes are used in an <edit-config> for a list or leaf-list node, and the "key" or "value" refers to a non-existing instance, the following error is returned:

```
error-tag:      bad-attribute
error-app-tag:  missing-instance
```

15. IANA Considerations

This document defines a registry for YANG module and submodule names. The name of the registry is "YANG Module Names".

The registry shall record for each entry:

- o the name of the module or submodule
- o for modules, the assigned XML namespace
- o for modules, the prefix of the module
- o for submodules, the name of the module it belongs to
- o a reference to the (sub)module's documentation (e.g., the RFC number)

There are no initial assignments.

For allocation, RFC publication is required as per RFC 5226 [RFC5226]. All registered YANG module names MUST comply with the rules for identifiers stated in Section 6.2, and MUST have a module name prefix.

The module name prefix 'ietf-' is reserved for IETF stream documents [RFC4844], while the module name prefix 'irtf-' is reserved for IRTF stream documents. Modules published in other RFC streams MUST have a similar suitable prefix.

All module and submodule names in the registry MUST be unique.

All XML namespaces in the registry MUST be unique.

This document registers two URIs for the YANG and YIN XML namespaces in the IETF XML registry [RFC3688]. Following the format in RFC 3688, the following have been registered.

URI: urn:ietf:params:xml:ns:yang:1
URI: urn:ietf:params:xml:ns:yang:1

Registrant Contact: The IESG.

XML: N/A, the requested URIs are XML namespaces.

This document registers one capability identifier URN from the
"Network Configuration Protocol (NETCONF) Capability URNs" registry:

urn:ietf:params:netconf:capability:yang-library:1.0

This document registers two new media types as defined in the
following sections.

15.1. Media type application/yang

MIME media type name: application

MIME subtype name: yang

Mandatory parameters: none

Optional parameters: none

Encoding considerations: 8-bit

Security considerations: See Section 15 in RFC XXXX

Interoperability considerations: None

Published specification: RFC XXXX

Applications that use this media type:

YANG module validators, web servers used for downloading YANG modules, email clients, etc.

Additional information:

Magic Number: None

File Extension: .yang

Macintosh file type code: 'TEXT'

Personal and email address for further information:

Martin Bjorklund <mbj@tail-f.com>

Intended usage: COMMON

Author:

This specification is a work item of the IETF NETMOD working group, with mailing list address <netmod@ietf.org>.

Change controller:

The IESG <iesg@ietf.org>

15.2. Media type application/yin+xml

MIME media type name: application

MIME subtype name: yin+xml

Mandatory parameters: none

Optional parameters:

"charset": This parameter has identical semantics to the charset parameter of the "application/xml" media type as specified in [RFC3023].

Encoding considerations:

Identical to those of "application/xml" as described in [RFC3023], Section 3.2.

Security considerations: See Section 15 in RFC XXXX

Interoperability considerations: None

Published specification: RFC XXXX

Applications that use this media type:

YANG module validators, web servers used for downloading YANG modules, email clients, etc.

Additional information:

Magic Number: As specified for "application/xml" in [RFC3023], Section 3.2.

File Extension: .yin

Macintosh file type code: 'TEXT'

Personal and email address for further information:

Martin Bjorklund <mbj@tail-f.com>

Intended usage: COMMON

Author:

This specification is a work item of the IETF NETMOD working group, with mailing list address <netmod@ietf.org>.

Change controller:

The IESG <iesg@ietf.org>

16. Security Considerations

This document defines a language with which to write and read descriptions of management information. The language itself has no security impact on the Internet.

The same considerations are relevant as for the base NETCONF protocol (see [RFC6241], Section 9).

Data modeled in YANG might contain sensitive information. RPCs or notifications defined in YANG might transfer sensitive information.

Security issues are related to the usage of data modeled in YANG. Such issues shall be dealt with in documents describing the data models and documents about the interfaces used to manipulate the data e.g., the NETCONF documents.

Data modeled in YANG is dependent upon:

- o the security of the transmission infrastructure used to send sensitive information.
- o the security of applications that store or release such sensitive information.
- o adequate authentication and access control mechanisms to restrict the usage of sensitive data.

YANG parsers need to be robust with respect to malformed documents. Reading malformed documents from unknown or untrusted sources could result in an attacker gaining privileges of the user running the YANG parser. In an extreme situation, the entire machine could be compromised.

17. Contributors

The following people all contributed significantly to the initial YANG document:

- Andy Bierman (Brocade)
- Balazs Lengyel (Ericsson)
- David Partain (Ericsson)
- Juergen Schoenwaelder (Jacobs University Bremen)
- Phil Shafer (Juniper Networks)

18. Acknowledgements

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19. ChangeLog

RFC Editor: remove this section upon publication as an RFC.

19.1. Version -04

- o Incorporated changes to ABNF grammar after review and errata for RFC 6020.
- o Included solution Y16-03.
- o Included solution Y49-04.
- o Included solution Y58-01.
- o Included solution Y59-01.

19.2. Version -03

- o Incorporated changes from WG reviews.
- o Included solution Y05-01.
- o Included solution Y10-01.
- o Included solution Y13-01.
- o Included solution Y28-02.
- o Included solution Y55-01 (parts of it was included in -01).

19.3. Version -02

- o Included solution Y02-01.
- o Included solution Y04-02.
- o Included solution Y11-01.
- o Included solution Y41-01.

- o Included solution Y56-01.

19.4. Version -01

- o Included solution Y01-01.
- o Included solution Y03-01.
- o Included solution Y06-02.
- o Included solution Y07-01.
- o Included solution Y14-01.
- o Included solution Y20-01.
- o Included solution Y23-01.
- o Included solution Y29-01.
- o Included solution Y30-01.
- o Included solution Y31-01.
- o Included solution Y35-01.

19.5. Version -00

- o Applied all reported errata for RFC 6020.
- o Updated YANG version to 1.1, and made the "yang-version" statement mandatory.

20. References

20.1. Normative References

[I-D.ietf-netconf-yang-library]

Bierman, A., Bjorklund, M., and K. Watsen, "YANG Module Library", draft-ietf-netconf-yang-library (work in progress), January 2015.

[ISO.10646]

International Organization for Standardization, "Information Technology - Universal Multiple-Octet Coded Character Set (UCS)", ISO Standard 10646:2003, 2003.

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [RFC3023] Murata, M., St. Laurent, S., and D. Kohn, "XML Media Types", RFC 3023, January 2001.
- [RFC3629] Yergeau, F., "UTF-8, a transformation format of ISO 10646", STD 63, RFC 3629, November 2003.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, January 2004.
- [RFC3986] Berners-Lee, T., Fielding, R., and L. Masinter, "Uniform Resource Identifier (URI): Generic Syntax", STD 66, RFC 3986, January 2005.
- [RFC4648] Josefsson, S., "The Base16, Base32, and Base64 Data Encodings", RFC 4648, October 2006.
- [RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 5226, May 2008.
- [RFC5234] Crocker, D. and P. Overell, "Augmented BNF for Syntax Specifications: ABNF", STD 68, RFC 5234, January 2008.
- [RFC5277] Chisholm, S. and H. Trevino, "NETCONF Event Notifications", RFC 5277, July 2008.
- [RFC6241] Enns, R., Bjorklund, M., Schoenwaelder, J., and A. Bierman, "Network Configuration Protocol (NETCONF)", RFC 6241, June 2011.
- [RFC7405] Kyzivat, P., "Case-Sensitive String Support in ABNF", RFC 7405, December 2014.
- [XML-NAMES]
Hollander, D., Tobin, R., Thompson, H., Bray, T., and A. Layman, "Namespaces in XML 1.0 (Third Edition)", World Wide Web Consortium Recommendation REC-xml-names-20091208, December 2009,
<<http://www.w3.org/TR/2009/REC-xml-names-20091208>>.
- [XPATH]
Clark, J. and S. DeRose, "XML Path Language (XPath) Version 1.0", World Wide Web Consortium Recommendation REC-xpath-19991116, November 1999,
<<http://www.w3.org/TR/1999/REC-xpath-19991116>>.

[XSD-TYPES]

Malhotra, A. and P. Biron, "XML Schema Part 2: Datatypes Second Edition", World Wide Web Consortium Recommendation REC-xmlschema-2-20041028, October 2004, <<http://www.w3.org/TR/2004/REC-xmlschema-2-20041028>>.

20.2. Informative References

- [RFC2578] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Structure of Management Information Version 2 (SMIv2)", STD 58, RFC 2578, April 1999.
- [RFC2579] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Textual Conventions for SMIv2", STD 58, RFC 2579, April 1999.
- [RFC3780] Strauss, F. and J. Schoenwaelder, "SMIng - Next Generation Structure of Management Information", RFC 3780, May 2004.
- [RFC4844] Daigle, L. and Internet Architecture Board, "The RFC Series and RFC Editor", RFC 4844, July 2007.
- [RFC6020] Bjorklund, M., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, October 2010.
- [XPath2.0] Berglund, A., Boag, S., Chamberlin, D., Fernandez, M., Kay, M., Robie, J., and J. Simeon, "XML Path Language (XPath) 2.0", World Wide Web Consortium Recommendation REC-xpath20-20070123, January 2007, <<http://www.w3.org/TR/2007/REC-xpath20-20070123>>.
- [XSLT] Clark, J., "XSL Transformations (XSLT) Version 1.0", World Wide Web Consortium Recommendation REC-xslt-19991116, November 1999, <<http://www.w3.org/TR/1999/REC-xslt-19991116>>.

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