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YANG Packages  
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## Abstract

This document defines YANG packages, a versioned organizational structure holding a set of related YANG modules, that collectively define a YANG schema. It describes how YANG instance data documents are used to define YANG packages, and how the YANG library information published by a server can be augmented with packages related information.

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YANG Packages

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## Table of Contents

<a href="#">1.</a>	<a href="#">Terminology and Conventions</a>	<a href="#">3</a>
<a href="#">2.</a>	<a href="#">Introduction</a>	<a href="#">4</a>
<a href="#">3.</a>	<a href="#">Background on YANG packages</a>	<a href="#">4</a>
<a href="#">4.</a>	<a href="#">Objectives</a>	<a href="#">5</a>
<a href="#">5.</a>	<a href="#">YANG Package Definition</a>	<a href="#">6</a>
<a href="#">5.1.</a>	<a href="#">Package definition rules</a>	<a href="#">7</a>
<a href="#">5.2.</a>	<a href="#">Package versioning</a>	<a href="#">7</a>
<a href="#">5.2.1.</a>	<a href="#">Updating a package with a new version</a>	<a href="#">8</a>
<a href="#">5.2.1.1.</a>	<a href="#">Non-Backwards-compatible changes</a>	<a href="#">8</a>
<a href="#">5.2.1.2.</a>	<a href="#">Backwards-compatible changes</a>	<a href="#">8</a>
<a href="#">5.2.1.3.</a>	<a href="#">Editorial changes</a>	<a href="#">9</a>
<a href="#">5.2.2.</a>	<a href="#">YANG Semantic Versioning for packages</a>	<a href="#">9</a>
<a href="#">5.2.3.</a>	<a href="#">Revision history</a>	<a href="#">10</a>
<a href="#">5.3.</a>	<a href="#">Package conformance</a>	<a href="#">10</a>
<a href="#">5.3.1.</a>	<a href="#">Use of YANG semantic versioning</a>	<a href="#">10</a>
<a href="#">5.3.2.</a>	<a href="#">Package checksums</a>	<a href="#">11</a>
<a href="#">5.4.</a>	<a href="#">Schema referential completeness</a>	<a href="#">11</a>
<a href="#">5.5.</a>	<a href="#">Package name scoping and uniqueness</a>	<a href="#">12</a>
<a href="#">5.5.1.</a>	<a href="#">Globally scoped packages</a>	<a href="#">12</a>
<a href="#">5.5.2.</a>	<a href="#">Server scoped packages</a>	<a href="#">12</a>
<a href="#">5.6.</a>	<a href="#">Submodules packages considerations</a>	<a href="#">13</a>
<a href="#">5.7.</a>	<a href="#">Package tags</a>	<a href="#">13</a>
<a href="#">6.</a>	<a href="#">YANG Packages instance data</a>	<a href="#">13</a>
<a href="#">7.</a>	<a href="#">YANG Packages additions to YANG library</a>	<a href="#">15</a>
<a href="#">7.1.</a>	<a href="#">Package List</a>	<a href="#">15</a>
<a href="#">7.2.</a>	<a href="#">Binding from schema to package</a>	<a href="#">15</a>
<a href="#">7.3.</a>	<a href="#">Tree diagram</a>	<a href="#">16</a>
<a href="#">8.</a>	<a href="#">YANG Packages Groupings</a>	<a href="#">18</a>
<a href="#">9.</a>	<a href="#">YANG packages as schema for YANG instance data document</a>	<a href="#">18</a>
<a href="#">10.</a>	<a href="#">YANG Modules</a>	<a href="#">19</a>
<a href="#">11.</a>	<a href="#">Security Considerations</a>	<a href="#">40</a>
<a href="#">12.</a>	<a href="#">IANA Considerations</a>	<a href="#">41</a>
<a href="#">13.</a>	<a href="#">Open Questions/Issues</a>	<a href="#">42</a>
<a href="#">14.</a>	<a href="#">Acknowledgements</a>	<a href="#">42</a>
<a href="#">15.</a>	<a href="#">References</a>	<a href="#">42</a>
<a href="#">15.1.</a>	<a href="#">Normative References</a>	<a href="#">42</a>
<a href="#">15.2.</a>	<a href="#">Informative References</a>	<a href="#">44</a>
<a href="#">Appendix A.</a>	<a href="#">Tree output for ietf-yang-library with package</a>	

augmentations . . . . .	<a href="#">45</a>
<a href="#">Appendix B.</a> Examples . . . . .	<a href="#">47</a>
<a href="#">B.1.</a> Example IETF Network Device YANG package . . . . .	<a href="#">47</a>
<a href="#">B.2.</a> Example IETF Basic Routing YANG package . . . . .	<a href="#">50</a>
<a href="#">B.3.</a> Package import conflict resolution example . . . . .	<a href="#">53</a>

<a href="#">Appendix C.</a> Possible alternative solutions . . . . .	<a href="#">56</a>
<a href="#">C.1.</a> Using module tags . . . . .	<a href="#">56</a>
<a href="#">C.2.</a> Using YANG library . . . . .	<a href="#">56</a>
Author's Address . . . . .	<a href="#">57</a>

## [1.](#) Terminology and Conventions

The key words "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](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

This document uses terminology introduced in the YANG versioning requirements draft [[I-D.verdt-netmod-yang-versioning-reqs](#)].

This document also makes of the following terminology introduced in the Network Management Datastore Architecture [[RFC8342](#)]:

- o datastore schema

This document also makes of the following terminology introduced in the YANG 1.1 Data Modeling Language [[RFC7950](#)]:

- o data node

In addition, this document defines the following terminology:

- o YANG schema: A datastore schema, not bound to any particular datastore.
- o YANG package: An organizational structure holding a collection of YANG modules related by some common purpose, normally defined in a YANG instance data file. A YANG package defines a YANG schema by specifying a set of YANG modules revisions, package versions, mandatory features, and deviations. YANG packages are defined in

## [Section 5.](#)

- o backwards-compatible (BC) change: When used in the context of a YANG module, it follows the definition in Section 3.1.1 of [\[I-D.verdt-netmod-yang-module-versioning\]](#). When used in the context of a YANG package, it follows the definition in [Section 5.2.1.2.](#)
- o non-backwards-compatible (NBC) change: When used in the context of a YANG module, it follows the definition in Section 3.1.2 of [\[I-D.verdt-netmod-yang-module-versioning\]](#). When used in the

context of a YANG package, it follows the definition in [Section 5.2.1.2.](#)

- o editorial change: When used in the context of a YANG module, it follows the definition of an 'editorial change' in 3.2 of [\[I-D.verdt-netmod-yang-semver\]](#). When used in the context of a YANG package, it follows the definition in [Section 5.2.1.3.](#)

## [2.](#) Introduction

This document defines and describes the YANG [\[RFC7950\]](#) constructs that are used to define and use YANG packages.

A YANG package is an organizational structure that groups a set of YANG modules together into a consistent versioned definition to serve a common purpose. For example, a YANG package could define the set of YANG modules required to implement an L2VPN service on a network device. YANG packages can themselves refer to, and reuse, other package definitions.

Non-normative examples of YANG packages are provided in the appendices.

## [3.](#) Background on YANG packages

It has long been acknowledged within the YANG community that network management using YANG requires a unit of organization and conformance that is broader in scope than individual YANG modules.

'The YANG Package Statement' [[I-D.bierman-netmod-yang-package](#)] proposed a YANG package mechanism based on new YANG language statements, where a YANG package is defined in a file similar to how YANG modules are defined, and would require enhancements to YANG compilers to understand the new statements used to define packages.

OpenConfig [[openconfigsemver](#)] describes an approach to versioning 'bundle releases' based on git tags. I.e. a set of modules, at particular versions, can be marked with the same release tag to indicate that they are known to interoperate together.

The NETMOD WG in general, and the YANG versioning design team in particular, are exploring solutions [[I-D.verdt-netmod-yang-solutions](#)] to the YANG versioning requirements, [[I-D.verdt-netmod-yang-versioning-reqs](#)]. Solutions to the versioning requirements can be split into several distinct areas. [[I-D.verdt-netmod-yang-module-versioning](#)] is focused on YANG versioning scoped to individual modules. The overall solution must also consider YANG versioning and conformance scoped to YANG schema.

YANG packages provide part of the solution for versioning YANG schema.

#### [4.](#) Objectives

The main goals of YANG package definitions include, but are not restricted to:

- o To provide an alternative, simplified, YANG conformance mechanism. Rather than conformance being performed against a set of individual YANG module revisions, features, and deviations, conformance can be more simply stated in terms of YANG packages, with a set of modifications (e.g. additional modules, deviations, or features).
- o To allow YANG schema to be specified in a concise way rather than having each server explicitly list all modules, revisions, and features. YANG package definitions can be defined in documents that are available offline, and accessible via a URL, rather than requiring explicit lists of modules to be shared between client and server. Hence, a YANG package must contain sufficient information to allow a client or server to precisely construct the

schema associated with the package.

- o To define a mainly linear versioned history of sets of modules versions that are known to work together. I.e. to help mitigate the problem where a client must manage devices from multiple vendors, and vendor A implements version 1.0.0 of module foo and version 2.0.0 of module bar, and vendor B implements version 2.0.0 of module foo and version 1.0.0 of module bar. For a client, trying to interoperate with multiple vendors, and many YANG modules, finding a consistent lowest common denominator set of YANG module versions may be difficult, if not impossible.

Protocol mechanisms of how clients can negotiate which packages or package versions are to be used for NETCONF/RESTCONF communications are outside the scope of this document, and are defined in [\[I-D.wilton-netmod-yang-ver-selection\]](#).

Finally, the package definitions proposed by this document are intended to be relatively basic in their definition and the functionality that they support. As industry gains experience using YANG packages, the standard YANG mechanisms of updating, or augmenting, YANG modules could also be used to extend the functionality supported by YANG packages, if required.

## [5.](#) YANG Package Definition

This document specifies an approach to defining YANG packages that is different to either of the approaches described in the background.

A YANG package is a versioned organizational structure defining a set of related YANG modules, packages, features, and deviations. A YANG package collectively defines a YANG schema.

Each YANG package has a name that SHOULD end with the suffix "-pkg". Package names are normally expected to be globally unique, but in some cases the package name may be locally scoped to a server or device, as described in [Section 5.5](#).

YANG packages are versioned using the same approaches described in

[[I-D.verdt-netmod-yang-module-versioning](#)] and [[I-D.verdt-netmod-yang-semver](#)]. This is described in further detail in [Section 5.2](#).

Each YANG package version, defines:

- some metadata about the package, e.g., description, tags, scoping, referential completeness, location information.

- a set of YANG modules, at particular revisions, that are implemented by servers that implement the package. The modules may contain deviations.

- a set of import-only YANG modules, at particular revisions, that are used 'import-only' by the servers that implement the package.

- a set of included YANG packages, at particular revisions, that are also implemented by servers that implement the package.

- a set of YANG module features that must be supported by servers that implement the package.

The structure for YANG package definitions uses existing YANG language statements, YANG Data Structure Extensions [[I-D.ietf-netmod-yang-data-ext](#)], and YANG Instance Data File Format [[I-D.ietf-netmod-yang-instance-file-format](#)].

YANG package definitions are available offline in YANG Instance Data Documents. Client applications can be designed to support particular package versions that they expect to interoperate with.

YANG package definitions are available from the server, via augmentations to YANG Library [[RFC8525](#)]. Rather than client

applications downloading the entire contents of YANG library to confirm that the server schema is compatible with the client, they can check, or download, a much shorter YANG package definition, and validate that it conforms to the expected schema.

YANG package definitions can also be used to define the schema associated with YANG instance data documents holding other, e.g., non packages related, instance data.

## [5.1.](#) Package definition rules

The following rules define how packages are defined:

A YANG package MAY represent a complete YANG schema or only part of a YANG schema with some module import dependencies missing, as described in [Section 5.4](#).

Packages definitions are hierarchical. A package can include other packages. Only a single version of a package can be included, and conflicting package includes (e.g. from descendant package includes) MUST be explicitly resolved by indicating which version takes precedence, and which versions are being replaced.

For each module implemented by a package, only a single revision of that module MUST be implemented. Multiple revisions of a module MAY be listed as import-only dependencies.

The revision of a module listed in the package 'module' list supersedes any 'implemented' revision of the module listed in an included package module list. The 'replaces-revision' leaf-list is used to indicate which 'implemented' or 'import-only' module revisions are replaced by this module revision. This allows a package to explicitly resolve conflicts between implemented module revisions in included packages.

The 'replaces-revision' leaf-list in the 'import-only-module' list can be used to exclude duplicate revisions of import-only modules from included packages. Otherwise, the import-only-modules for a package are the import-only-modules from all included packages combined with any modules listed in the packages import-only-module list.

## [5.2.](#) Package versioning

Individual versions of a YANG package are versioned using the "revision-label" scheme defined in section 3.3 of [\[I-D.verdt-netmod-yang-module-versioning\]](#).

### [5.2.1.](#) Updating a package with a new version

Package compatibility is fundamentally defined by how the YANG schema between two package versions has changed.

When a package definition is updated, the version associated with the package MUST be updated appropriately, taking into consideration the scope of the changes as defined by the rules below.

A package definition SHOULD define the previous version of the package in the 'previous-version' leaf unless it is the initial version of the package. If the 'previous-version' leaf is provided then the package definition MUST set the 'nbc-changes' leaf if the new version is non-backwards-compatible with respect to the package version defined in the 'previous-version' leaf.

#### [5.2.1.1](#). Non-Backwards-compatible changes

The following changes classify as NBC changes to a package definition:

- Changing an 'included-package' list entry to select a package version that is non-backwards-compatible to the prior package version, or removing a previously included package.

- Changing a 'module' or 'import-only-module' list entry to select a module revision that is non-backwards-compatible to the prior module revision, or removing a previously implemented module.

- Removing a feature from the 'mandatory-feature' leaf-list.

- Adding, changing, or removing a deviation that is considered a non-backwards-compatible change to the affected data node in the schema associated with the prior package version.

#### [5.2.1.2](#). Backwards-compatible changes

The following changes classify as BC changes to a package definition:

- Changing an 'included-package' list entry to select a package version that is backwards-compatible to the prior package version, or including a new package that does not conflict with any existing included package or module.

- Changing a 'module' or 'import-only-module' list entry to select a module revision that is backwards-compatible to the prior module revision, or including a new module to the package definition.

Adding a feature to the 'mandatory-feature' leaf-list.

Adding, changing, or removing a deviation that is considered a backwards-compatible change to the affected data node in the schema associated with the prior package version.

#### [5.2.1.3](#). Editorial changes

The following changes classify as editorial changes to a package definition:

Changing a 'included-package' list entry to select a package version that is classified as an editorial change relative to the prior package version.

Changing a 'module' or 'import-only-module' list entry to select a module revision that is classified as an editorial change relative to the prior module revision.

Any change to any metadata associated with a package definition that causes it to have a different checksum value.

#### [5.2.2](#). YANG Semantic Versioning for packages

YANG Semantic Versioning [[I-D.verdt-netmod-yang-semver](#)] MAY be used as an appropriate type of revision-label for the package version leaf.

If the format of the leaf matches the 'yangver:version' type specified in ietf-yang-semver.yang, then the package version leaf MUST be interpreted as a YANG semantic version number.

For YANG packages defined by the IETF, YANG semantic version numbers MUST be used as the version scheme for YANG packages.

The rules for incrementing the YANG package version number are equivalent to the semantic versioning rules used to version individual YANG modules, defined in section 3.2 of [[I-D.verdt-netmod-yang-semver](#)], but use the rules defined previously in [Section 5.2.1](#) to determine whether a change is classified as non-backwards-compatible, backwards-compatible, or editorial. Where available, the semantic version number of the referenced elements in the package (included packages or modules) can be used to help determine the scope of changes being made.

### [5.2.3.](#) Revision history

YANG packages do not contain a revision history. This is because packages may have many revisions and a long revision history would bloat the package definition. By recursively examining the 'previous-version' leaf of a package definition, a full revision history (including where non-backwards-compatible changes have occurred) can be dynamically constructed, if all package versions are available.

### [5.3.](#) Package conformance

YANG packages allows for conformance to be checked at a package level rather than requiring a client to download all modules, revisions, and deviations from the server to ensure that the datastore schema used by the server is compatible with the client.

YANG package conformance is analogous to how YANG [[RFC7950](#)] requires that servers either implement a module faithfully, or otherwise use deviations to indicate areas of non-conformance.

For a top level package representing a datastore schema, servers **MUST** implement the package definition faithfully, including all mandatory features.

Package definitions **MAY** modify the schema for directly or hierarchically included packages through the use of different module revisions or module deviations. If the schema of any included package is modified in a non-backwards-compatible way then it **MUST** be indicated by setting the 'nbc-modified' leaf to true.

#### [5.3.1.](#) Use of YANG semantic versioning

Using the YANG semantic versioning scheme for package version numbers and module revision labels can help with conformance. In the general case, clients should be able to determine the nature of changes between two package versions by comparing the version number.

This usually means that a client does not have to be restricted to

working only with servers that advertise exactly the same version of a package in YANG library. Instead, reasonable clients should be able to interoperate with any server that supports a package version that is backwards compatible to version that the client is designed for, assuming that the client is designed to ignore operational values for unknown data nodes.

For example, a client coded to support 'foo' package at version 1.0.0 should interoperate with a server implementing 'foo' package at

version 1.3.5, because the YANG semantic versioning rules require that package version 1.3.5 is backwards compatible to version 1.0.0.

This also has a relevance on servers that are capable of supporting version selection because they need not support every version of a YANG package to ensure good client compatibility. Choosing suitable minor versions within each major version number should generally be sufficient, particular if they can avoid NBC patch level changes (i.e. 'M' labeled versions).

#### [5.3.2.](#) Package checksums

Each YANG package definition may have a checksum associated with it to allow a client to validate that the package definition of the server matches the expected package definition without downloading the full package definition from the server.

The checksum for a package is calculated using the SHA-256 hash (XXX, reference) of the full file contents of the YANG package instance data file. This means that the checksum includes all whitespace and formatting, encoding, and all meta-data fields associated with the package and the instance data document).

The checksum for a module is calculated using the SHA-256 hash of the YANG module file definition. This means that the checksum includes all whitespace, formatting, and comments within the YANG module.

Packages that are locally scoped to a server may not have an offline instance data document available, and hence MAY not have a checksum.

The package definition allows URLs and checksums to be specified for all included packages, modules and submodules within the package

definition. Checksums SHOULD be included in package definitions to validate the full integrity of the package.

On a server, package checksums SHOULD also be provided for the top level packages associated with the datastore schema.

#### [5.4.](#) Schema referential completeness

A YANG package may represent a schema that is 'referentially complete', or 'referentially incomplete', indicated in the package definition by the 'complete' flag.

If all import statements in all YANG modules included in the package (either directly, or through included packages) can be resolved to a module revision defined with the YANG package definition, then the package is classified as referentially complete. Conversely, if one

or more import statements cannot be resolved to a module specified as part of the package definition, then the package is classified as referentially incomplete.

A package that represents the exact contents of a datastore schema MUST always be referentially complete.

Referentially incomplete packages can be used, along with locally scoped packages, to represent an update to a device's datastore schema as part of an optional software hot fix. E.g., the base software is made available as a complete globally scoped package. The hot fix is made available as an incomplete globally scoped package. A device's datastore schema can define a local package that implements the base software package updated with the hot fix package.

Referentially incomplete packages could also be used to group sets of logically related modules together, but without requiring a fixed dependency on all imported 'types' modules (e.g., iana-if-types.yang), instead leaving the choice of specific revisions of 'types' modules to be resolved when the package definition is used.

#### [5.5.](#) Package name scoping and uniqueness

YANG package names can be globally unique, or locally scoped to a

particular server or device.

#### [5.5.1.](#) Globally scoped packages

The name given to a package MUST be globally unique, and it MUST include an appropriate organization prefix in the name, equivalent to YANG module naming conventions.

Ideally a YANG instance data document defining a particular package version would be publicly available at one or more URLs.

#### [5.5.2.](#) Server scoped packages

Package definitions may be scoped to a particular server by setting the 'is-local' leaf to true in the package definition.

Locally scoped packages MAY have a package name that is not globally unique.

Locally scoped packages MAY have a definition that is not available offline from the server in a YANG instance data document.

#### [5.6.](#) Submodules packages considerations

As defined in [[RFC7950](#)] and [[I-D.verdt-netmod-yang-semver](#)], YANG conformance and versioning is specified in terms of particular revisions of YANG modules rather than for individual submodules.

However, YANG package definitions also include the list of submodules included by a module, primarily to provide a location of where the submodule definition can be obtained from, allowing a YANG schema to be fully constructed from a YANG package instance-data file definition.

#### [5.7.](#) Package tags

[[I-D.ietf-netmod-module-tags](#)] defines YANG module tags as a mechanism to annotate a module definition with additional metadata. Tags MAY also be associated to a package definition via the 'tags' leaf-list. The tags use the same registry and definitions used by YANG module

tags.

## 6. YANG Packages instance data

YANG packages SHOULD be defined as YANG instance data documents [[I-D.ietf-netmod-yang-instance-file-format](#)] using the YANG schema below to define the package data itself.

The format of the YANG package instance file MUST follow the following rules:

The file SHOULD be encoded in JSON.

The name of the file SHOULD follow the format "<package-name>@<version>.json".

The package name MUST be specified in both the instance-data-set 'name' and package 'name' leafs.

The 'description' field of the instance-data-set SHOULD be "YANG package definition".

The 'timestamp', 'organization', 'contact' fields are defined in both the instance-data-set metadata and the YANG package metadata. Package definitions SHOULD only define these fields as part of the package definition. If any of these fields are populated in the instance-data-set metadata then they MUST contain the same value as the corresponding leaves in the package definition.

The 'revision' list in the instance data document SHOULD NOT be used, since versioning is handled by the package definition.

The instance data document for each version of a YANG package SHOULD be made available at one of more locations accessible via URLs. If one of the listed locations defines a definitive reference implementation for the package definition then it MUST be listed as the first entry in the list.

The "ietf-yang-package" YANG module has the following structure:

module: ietf-yang-package

```
structure package:
  +-- name pkg-identifier
  +-- version rev:revision-label
  +-- timestamp? yang:date-and-time
  +-- organization? string
  +-- contact? string
  +-- description? string
  +-- reference? string
  +-- location* inet:uri
  +-- complete? boolean
  +-- local? boolean
  +-- previous-version? rev:revision-label
  +-- nbc-changes? boolean
  +-- tag* tags:tag
  +-- mandatory-feature* scoped-feature
  +-- included-package* [name version]
  |   +-- name pkg-identifier
  |   +-- version rev:revision-label
  |   +-- replaces-version* rev:revision-label
  |   +-- nbc-modified? boolean
  |   +-- location* inet:uri
  |   +-- checksum? pkg-types:sha-256-hash
  +-- module* [name]
  |   +-- name yang:yang-identifier
  |   +-- revision? rev:revision-date-or-label
  |   +-- replaces-revision* rev:revision-date-or-label
  |   +-- namespace? inet:uri
  |   +-- location* inet:uri
  |   +-- checksum? pkg-types:sha-256-hash
  |   +-- submodule* [name]
  |       +-- name yang:yang-identifier
  |       +-- revision rev:revision-identifier
  |       +-- location* inet:uri
  |       +-- checksum? pkg-types:sha-256-hash
```

```
+-- import-only-module* [name revision]
  +-- name yang:yang-identifier
  +-- revision rev:revision-date-or-label
  +-- replaces-revision* rev:revision-date-or-label
```

```

+-- namespace?          inet:uri
+-- location*           inet:uri
+-- checksum?          pkg-types:sha-256-hash
+-- submodule* [name]
    +-- name            yang:yang-identifier
    +-- revision        rev:revision-identifier
    +-- location*       inet:uri
    +-- checksum?       pkg-types:sha-256-hash

```

## [7. YANG Packages additions to YANG library](#)

### [7.1. Package List](#)

The main addition is a top level 'yang-library/package' list that lists all versions of all packages known to the server. Each package defines a potentially incomplete YANG schema, built from included packages and module-sets. The use of module-sets allows the module definitions to be shared with the existing YANG library schema definitions. The existing rule of RFC 7995bis related to combining modules-sets also applies here, i.e. The combined set of modules defined by the module-sets MUST NOT contain modules implemented at different revisions. I.e. the module-sets leaf-list is directly equivalent to the explicit module and import-only-module lists in the instance data YANG package definition.

The 'yang-library/package' list MAY include multiple versions of a particular package. E.g. if the server is capable of allowing clients to select which package versions should be used by the server.

### [7.2. Binding from schema to package](#)

The second augmentation is to allow a server to optionally indicate that a schema definition directly relates to a package. Since YANG packages are available offline, it may be sufficient for a client to only check that a compatible version of the YANG package is being implemented by the server without fetching and comparing the full module list.

If a server indicates that its schema maps to a particular package then it MUST support all features listed in the mandatory-feature list defined as part of that package, and it MUST NOT have any non-backwards-compatible deviations to the modules defined by the

package. A server MAY implement features not specified in the package's mandatory-feature list.

If a server cannot faithfully implement a package then it can define a new package to accurately report what it does implement. The new package can include the original package as an included package, and the new package can define additional modules containing deviations to the modules in the original package, allowing the new package to accurately describe the server behavior. There is no specific mechanism provided to indicate that a mandatory-feature is not supported on a server, but deviations MAY be used to disable functionality predicated by an if-feature statement.

### [7.3.](#) Tree diagram

The "ietf-yang-library-packages" YANG module has the following structure:

```
module: ietf-yl-packages
  augment /yanglib:yang-library:
    +--ro package* [name version]
      +--ro name pkg-identifier
      +--ro version rev:revision-label
      +--ro timestamp? yang:date-and-time
      +--ro organization? string
      +--ro contact? string
      +--ro description? string
      +--ro reference? string
      +--ro location* inet:uri
      +--ro complete? boolean
      +--ro local? boolean
      +--ro previous-version? rev:revision-label
      +--ro nbc-changes? boolean
      +--ro tag* tags:tag
      +--ro mandatory-feature* scoped-feature
      +--ro included-package* [name version]
        | +--ro name pkg-identifier
        | +--ro version rev:revision-label
        | +--ro replaces-version* rev:revision-label
        | +--ro nbc-modified? boolean
        | +--ro location* inet:uri
        | +--ro checksum? pkg-types:sha-256-hash
      +--ro module-set*
        | -> /yanglib:yang-library/module-set/name
      +--ro checksum? pkg-types:sha-256-hash
  augment /yanglib:yang-library/yanglib:schema:
    +--ro package
      +--ro name?
        | -> /yanglib:yang-library/package/name
      +--ro version? leafref
      +--ro checksum? pkg-types:sha-256-hash
      +--ro supported-optional-feature* pkg-types:scoped-feature
  augment /yanglib:yang-library/yanglib:module-set/yanglib:module:
    +--ro replaces-revision* rev:revision-date-or-label
    +--ro checksum? pkg-types:sha-256-hash
  augment /yanglib:yang-library/yanglib:module-set/yanglib:module
    /yanglib:submodule:
      +--ro checksum? pkg-types:sha-256-hash
```

```

augment /yanglib:yang-library/yanglib:module-set
    /yanglib:import-only-module:
    +--ro replaces-revision*   rev:revision-date-or-label
    +--ro checksum?            pkg-types:sha-256-hash
augment /yanglib:yang-library/yanglib:module-set
    /yanglib:import-only-module/yanglib:submodule:
    +--ro checksum?           pkg-types:sha-256-hash

```

## [8.](#) YANG Packages Groupings

Groupings for YANG packages related constructs are provided in a 'types' module for use by the instance-data and YANG library constructs described previously. They are also available to be used by other modules that have a need for YANG packages information.

The "ietf-yang-package-types" YANG module has the following structure:

module: ietf-yang-package-types

```

grouping yang-pkg-identification-leafs
  +-- name          pkg-identifier
  +-- version       rev:revision-label
grouping yang-pkg-common-leafs
  +-- timestamp?    yang:date-and-time
  +-- organization? string
  +-- contact?      string
  +-- description?  string
  +-- reference?    string
  +-- location*     inet:uri
  +-- complete?     boolean
  +-- local?        boolean
  +-- previous-version? rev:revision-label
  +-- nbc-changes?  boolean
  +-- tag*          tags:tag
  +-- mandatory-feature* scoped-feature
  +-- included-package* [name version]
    +-- name          pkg-identifier
    +-- version       rev:revision-label
    +-- replaces-version* rev:revision-label

```

```

+-- nbc-modified?      boolean
+-- location*          inet:uri
+-- checksum?          pkg-types:sha-256-hash

```

## [9.](#) YANG packages as schema for YANG instance data document

YANG package definitions can be used as the schema definition for YANG instance data documents. When using a package schema, the name of the package MUST be specified, a package checksum and/or URL to the package definition MAY also be provided.

Wilton

Expires April 25, 2020

[Page 18]

---

Internet-Draft

YANG Packages

October 2019

The "ietf-yang-inst-data-pkg" YANG module has the following structure:

```

module: ietf-yang-inst-data-pkg

```

```

  augment-structure /yid:instance-data-set/yid:content-schema-spec:
    +--:(pkg-schema)
      +-- pkg-schema
      +-- package      pkg-types:pkg-identifier
      +-- location*    inet:uri
      +-- checksum?    pkg-types:sha-256-hash

```

## [10.](#) YANG Modules

The YANG module definitions for the modules described in the previous sections.

```

<CODE BEGINS> file "ietf-yang-package-types@2019-09-11.yang"
module ietf-yang-package-types {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-yang-package-types";
  prefix "pkg-types";

```

```

import ietf-yang-revisions {
    prefix rev;
    reference "XXXX: Updated YANG Module Revision Handling";
}

import ietf-yang-types {
    prefix yang;
    rev:revision-or-derived 2013-07-15;
    reference "RFC 6991: Common YANG Data Types.";
}

import ietf-inet-types {
    prefix inet;
    reference "RFC 6991: Common YANG Data Types.";
}

import ietf-module-tags {
    prefix tags;
    reference "RFC XXX: YANG Module Tags.";
}

organization

```

Wilton

Expires April 25, 2020

[Page 19]

---

Internet-Draft

YANG Packages

October 2019

"IETF NETMOD (Network Modeling) Working Group";

contact

"WG Web: <<http://tools.ietf.org/wg/netmod/>>

WG List: <<mailto:netmod@ietf.org>>

Author: Rob Wilton  
<<mailto:rwilton@cisco.com>>;

description

"This module provides type and grouping definitions for YANG packages.

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```
// RFC Ed.: update the date below with the date of RFC publication
// and remove this note.
// RFC Ed.: replace XXXX with actual RFC number and remove this
// note.
revision 2019-09-11 {
    rev:revision-label 0.1.0;
    description
        "Initial revision";
    reference
        "RFC XXXX: YANG Packages";
}

/*
 * Typedefs
 */
```

```
typedef pkg-identifier {
    type yang:yang-identifier;
    description
        "Package identifiers are typed as YANG identifiers.";
}

typedef scoped-feature {
    type string {
        pattern '[a-zA-Z_][a-zA-Z0-9\-\_\.]*:[a-zA-Z_][a-zA-Z0-9\-\_\.]*';
    }
    description
        "Represents a feature name scoped to a particular module,
```

```

        identified as the '<module-name>:<feature-name>', where both
        <module-name> and <feature-name> are YANG identifier strings,
        as defiend by Section 12 or RFC 6020.";
    reference
        "RFC XXXX, YANG Packages.";
}

typedef sha-256-hash {
    type string {
        length "64";
        pattern "[0-9a-fA-F]*";
    }
    description
        "A SHA-256 hash represented as a hexadecimal string.

        Used as the checksum for modules, submodules and packages in a
        YANG package definition.

        For modules and submodules the SHA-256 hash is calculated on
        the contents of the YANG file defining the module/submodule.

        For packages the SHA-256 hash is calculated on the file
        containing the YANG instance data document holding the package
        definition";
}

/*
 * Groupings
 */

grouping yang-pkg-identification-leafs {
    description
        "Parameters for identifying a specific version of a YANG
        package";
}

```

```

leaf name {
    type pkg-identifier;
    mandatory true;
    description
        "The YANG package name.";
}

```

```

}

leaf version {
    type rev:revision-label;
    mandatory true;
    description
        "Uniquely identifies a particular version of a YANG package.

        Follows the definition for revision labels defined in
draft-verdt-nemod-yang-module-versioning, section XXX";
}
}

grouping yang-pkg-common-leafs {
    description
        "Defines definitions common to all YANG package definitions.";

    leaf timestamp {
        type yang:date-and-time;

        description
            "An optional timestamp for when this package was created.
            This does not need to be unique across all versions of a
            package.";
    }

    leaf organization {
        type string;

        description "Organization responsible for this package";
    }

    leaf contact {
        type string;

        description
            "Contact information for the person or organization to whom
            queries concerning this package should be sent.";
    }

    leaf description {
        type string;
    }
}

```

```

    description "Provides a description of the package";
}

leaf reference {
    type string;

    description "Allows for a reference for the package";
}

leaf-list location {
    type inet:uri;
    description
        "Contains a URL that represents where an instance data file
        for this YANG package can be found.

        This leaf will only be present if there is a URL
        available for retrieval of the schema for this entry.

        If multiple locations are provided, then the first location
        in the leaf-list MUST be the definitive location that
        uniquely identifies this package";
}

leaf complete {
    type boolean;
    default true;
    description
        "Indicates whether the schema defined by this package is
        referentially complete. I.e. all module imports can be
        resolved to a module explicitly defined in this package or
        one of the included packages.";
}

leaf local {
    type boolean;
    default false;
    description
        "Defines that the package definition is local to the server,
        and the name of the package MAY not be unique, and the
        package definition MAY not be available in an offline file.

        Local packages can be used when the schema for the device
        can be changed at runtime through the addition or removal of
        software packages, or hot fixes.";
}

leaf previous-version {
    type rev:revision-label;

```

```
    description
      "The previous package version that this version has been
      derived from. This leaf allows a full version history graph
      to be constructed if required.";
  }

  leaf nbc-changes {
    type boolean;
    default false;
    description
      "Indicates whether the defined package version contains
      non-backwards-compatible changes relative to the package
      version defined in the 'previous-version' leaf.";
  }

  leaf-list tag {
    type tags:tag;
    description
      "Tags associated with a YANG package. Module tags defined in
      XXX, ietf-netmod-module-tags can be used here but with the
      modification that the tag applies to the entire package
      rather than a specific module. See the IANA 'YANG Module
      Tag Prefix' registry for reserved prefixes and the IANA
      'YANG Module IETF Tag' registry for IETF standard tags.";
  }

  leaf-list mandatory-feature {
    type scoped-feature;
    description
      "Lists features from any modules included in the package that
      MUST be supported by any server implementing the package.

      Features already specified in a 'mandatory-feature' list of
      any included package MUST also be supported by server
      implementations and do not need to be repeated in this list.

      All other features defined in modules included in the
      package are OPTIONAL to implement.

      Features are identified using <module-name>:<feature-name>";
  }
```

```
list included-package {
  key "name version";
  description
    "An entry in this list represents a package that is included
    as part of the package definition, or an indirectly included
    package that is changed in a non backwards compatible way."
```

It can be used to resolve inclusion of conflicting package versions by explicitly specifying which package version is used.

If included packages implement different revisions or versions of the same module, then an explicit entry in the module list **MUST** be provided to select the specific module version 'implemented' by this package definition.

If the schema for any packages that are included, either directly or indirectly via another package include, are changed in any non-backwards-compatible way then they **MUST** be explicitly listed in the included-packages list with the 'nbc-modified' leaf set to true.

For import-only modules, the 'replaces-revision' leaf-list can be used to select the specific module versions used by this package.";

```
reference
  "XXX";
```

```
uses yang-pkg-identification-leafs;
```

```
leaf-list replaces-version {
  type rev:revision-label;
  description
    "Gives the version of an included package version that
    is replaced by this included package revision.";
}
```

```
leaf nbc-modified {
  type boolean;
  default false;
  description
    "Set to true if any data nodes in this package are modified
```

```

        in a non backwards compatible way, either through the use
        of deviations, or because one of the modules has been
        replaced by an incompatible revision. This could also
        occur if a module's revision was replaced by an earlier
        revision that had the effect of removing some data
        nodes.";
    }

    leaf-list location {
        type inet:uri;
        description
            "Contains a URL that represents where an instance data file
            for this YANG package can be found."
    }

```

This leaf will only be present if there is a URL available for retrieval of the schema for this entry.

If multiple locations are provided, then the first location in the leaf-list MUST be the definitive location that uniquely identifies this package";

```

    }

    leaf checksum {
        type pkg-types:sha-256-hash;
        description
            "The SHA-256 hash calculated on the textual package
            definition, represented as a hexadecimal string.";
    }
}
}
}
<CODE ENDS>

```

```

<CODE BEGINS> file "ietf-yang-package@2019-09-11.yang"
module ietf-yang-package {
    yang-version 1.1;
    namespace "urn:ietf:params:xml:ns:yang:ietf-yang-package";
    prefix pkg;

    import ietf-yang-revisions {

```

```

    prefix rev;
    reference "XXXX: Updated YANG Module Revision Handling";
}

import ietf-yang-package-types {
    prefix pkg-types;
    rev:revision-or-derived 0.1.0;
    reference "RFC XXX: YANG Schema Versioning.";
}

import ietf-yang-structure-ext {
    prefix sx;
    reference "RFC XXX: YANG Data Structure Extensions.";
}

import ietf-yang-types {
    prefix yang;
    rev:revision-or-derived 2013-07-15;
    reference "RFC 6991: Common YANG Data Types.";
}

```

```

import ietf-inet-types {
    prefix inet;
    reference "RFC 6991: Common YANG Data Types.";
}

```

```

organization
  "IETF NETMOD (Network Modeling) Working Group";

```

```

contact
  "WG Web:    <http://tools.ietf.org/wg/netmod/>
  WG List:    <mailto:netmod@ietf.org>

```

```

  Author:     Rob Wilton
              <mailto:rwilton@cisco.com>;

```

```

description
  "This module provides a definition of a YANG package, which is
  used as the schema for an YANG instance data document specifying
  a YANG package.

```

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```
// RFC Ed.: update the date below with the date of RFC publication
// and remove this note.
// RFC Ed.: replace XXXX with actual RFC number and remove this
// note.
revision 2019-09-11 {
  rev:revision-label 0.1.0;
  description
    "Initial revision";
  reference
```

Wilton

Expires April 25, 2020

[Page 27]

---

Internet-Draft

YANG Packages

October 2019

```
    "RFC XXXX: YANG Packages";
  }
```

```
/*
 * Top-level structure
 */
```

```
sx:structure package {
  description
    "Defines a YANG package.
```

```
    Intended to be used to specify YANG package within an instance
    data document.";
```

```

uses pkg-types:yang-pkg-identification-leafs;
uses pkg-types:yang-pkg-common-leafs;

list module {
  key "name";
  description
    "An entry in this list represents a module that must be
    implemented by a server implementing this package, as per
    RFC 7950 section 5.6.5, with a particular set of supported
    features and deviations.

    A entry in this list overrides any module revision
    'implemented' by an included package. Any replaced module
    revision SHOULD also be listed in the 'replaces-revision'
    list.";
  reference
    "RFC 7950: The YANG 1.1 Data Modeling Language.";

  leaf name {
    type yang:yang-identifier;
    mandatory true;
    description
      "The YANG module name.";
  }

  leaf revision {
    type rev:revision-date-or-label;
    description
      "The YANG module revision date or revision-label.

      If no revision statement is present in the YANG module,
      this leaf is not instantiated.";
  }
}

```

```

leaf-list replaces-revision {
  type rev:revision-date-or-label;
  description
    "Gives the revision of an module (implemented or
    import-only) defined in an included package that is
    replaced by this implemented module revision.";
}

```

```

leaf namespace {
    type inet:uri;
    description
        "The XML namespace identifier for this module.";
}

leaf-list location {
    type inet:uri;
    description
        "Contains a URL that represents the YANG schema resource
        for this module.

        This leaf will only be present if there is a URL available
        for retrieval of the schema for this entry.";
}

leaf checksum {
    type pkg-types:sha-256-hash;
    description
        "The SHA-256 hash calculated on the textual module
        definition, represented as a hexadecimal string.";
}

list submodule {
    key "name";
    description
        "Each entry represents one submodule within the
        parent module.";

    leaf name {
        type yang:yang-identifier;
        description
            "The YANG submodule name.";
    }

    leaf revision {
        type rev:revision-identifier;
        mandatory true;
        description
            "The YANG submodule revision date.  If the parent module

```

```

        include statement for this submodule includes a revision
        date then it MUST match this leaf's value.";
    }

    leaf-list location {
        type inet:uri;
        description
            "Contains a URL that represents the YANG schema resource
            for this submodule.

            This leaf will only be present if there is a URL
            available for retrieval of the schema for this entry.";
    }

    leaf checksum {
        type pkg-types:sha-256-hash;
        description
            "The SHA-256 hash calculated on the textual submodule
            definition, represented as a hexadecimal string.";
    }
}

list import-only-module {
    key "name revision";
    description
        "An entry in this list indicates that the server imports
        reusable definitions from the specified revision of the
        module, but does not implement any protocol accessible
        objects from this revision.

        Multiple entries for the same module name MAY exist. This
        can occur if multiple modules import the same module, but
        specify different revision-dates in the import statements.";

    leaf name {
        type yang:yang-identifier;
        description
            "The YANG module name.";
    }

    leaf revision {
        type rev:revision-date-or-label;
        description
            "The YANG module revision date or revision-label.

            If no revision statement is present in the YANG module,
            this leaf is not instantiated.";
    }
}

```

Internet-Draft

YANG Packages

October 2019

```
}

leaf-list replaces-revision {
  type rev:revision-date-or-label;
  description
    "Gives the revision of an import-only-module defined in an
    included package that is replaced by this
    import-only-module revision.";
}

leaf namespace {
  type inet:uri;
  description
    "The XML namespace identifier for this module.";
}

leaf-list location {
  type inet:uri;
  description
    "Contains a URL that represents the YANG schema resource
    for this module.

    This leaf will only be present if there is a URL available
    for retrieval of the schema for this entry.";
}

leaf checksum {
  type pkg-types:sha-256-hash;
  description
    "The SHA-256 hash calculated on the textual submodule
    definition, represented as a hexadecimal string.";
}

list submodule {
  key "name";
  description
    "Each entry represents one submodule within the
    parent module.";

  leaf name {
    type yang:yang-identifier;
    description
      "The YANG submodule name.";
```

```

    }

    leaf revision {
        type rev:revision-identifier;
        mandatory true;
    }

```

```

        description
            "The YANG submodule revision date. If the parent module
            include statement for this submodule includes a revision
            date then it MUST match this leaf's value.";
    }

    leaf-list location {
        type inet:uri;
        description
            "Contains a URL that represents the YANG schema resource
            for this submodule.

            This leaf will only be present if there is a URL
            available for retrieval of the schema for this entry.";
    }

    leaf checksum {
        type pkg-types:sha-256-hash;
        description
            "The SHA-256 hash calculated on the textual submodule
            definition, represented as a hexadecimal string.";
    }
}
}
}
}
}
<CODE ENDS>

```

```

<CODE BEGINS> file "ietf-yl-packages@2019-09-11.yang"
module ietf-yl-packages {
    yang-version 1.1;
    namespace "urn:ietf:params:xml:ns:yang:ietf-yl-packages";
    prefix yl-pkg;
}

```

```
import ietf-yang-revisions {
    prefix rev;
    reference "XXXX: Updated YANG Module Revision Handling";
}

import ietf-yang-package-types {
    prefix pkg-types;
    reference "RFC XXX: YANG Packages.";
}

import ietf-yang-library {
    prefix yanglib;
```

Wilton

Expires April 25, 2020

[Page 32]

---

Internet-Draft

YANG Packages

October 2019

```
    reference "RFC 7895bis: YANG Library";
}
```

```
organization
    "IETF NETMOD (Network Modeling) Working Group";
```

```
contact
    "WG Web:   <http://tools.ietf.org/wg/netmod/>
    WG List:  <mailto:netmod@ietf.org>
```

```
    Author:   Rob Wilton
              <mailto:rwilton@cisco.com>";
```

```
description
```

```
"This module provides defined augmentations to YANG library to
allow a server to report YANG package information.
```

```
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authors of the code. All rights reserved.
```

```
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```

```
This version of this YANG module is part of RFC XXXX; see
the RFC itself for full legal notices.
```

The key words '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 \(RFC 2119\)](#) ([RFC 8174](#)) when, and only when, they appear in all capitals, as shown here.";

```
// RFC Ed.: update the date below with the date of RFC publication
// and remove this note.
// RFC Ed.: replace XXXX with actual RFC number and remove this
// note.
revision 2019-09-11 {
  rev:revision-label 0.1.0;
  description
    "Initial revision";
  reference
    "RFC XXXX: YANG Packages";
}
```

Wilton

Expires April 25, 2020

[Page 33]

---

Internet-Draft

YANG Packages

October 2019

```
/*
 * Augmentations
 */

augment "/yanglib:yang-library" {
  description "Add YANG package definitions into YANG library";

  list package {
    key "name version";
    config "false";

    description
      "Defines the package available on this server.";

    uses pkg-types:yang-pkg-identification-leafs;
    uses pkg-types:yang-pkg-common-leafs;

    leaf-list module-set {
      type leafref {
        path "/yanglib:yang-library/yanglib:module-set/" +
          "yanglib:name";
      }
    }
  }
}
```

```

    description
      "Describes any modules in addition to, and replacing, and
      modules defined in the included packages.

      If a non import-only module appears in multiple module
      sets, then the module revision and the associated features
      and deviations MUST be identical.";
  }

  leaf checksum {
    type pkg-types:sha-256-hash;
    description
      "The SHA-256 hash calculated on the textual package
      definition, represented as a hexadecimal string.";
  }
}

augment "/yanglib:yang-library/yanglib:schema" {
  description
    "Allow datastore schema to be related to a YANG package";

  container package {
    leaf name {
      type leafref {
        path "/yanglib:yang-library/package/name";
      }
    }
  }
}

```

```

  }
  description
    "The name of the package this schema relates to.

    The referenced package MUST represent a referentially
    complete schema";
}

leaf version {
  type leafref {
    path '/yanglib:yang-library/'
      + 'package[name = current()/../name]/version';
  }
  description

```

```

        "The version number of the package this schema relates
        to.";
    }

    leaf checksum {
        type pkg-types:sha-256-hash;
        description
            "The checksum of the package this schema relates to,
            calculated on the 'YANG instance data file' package
            definition.

            This leaf MAY be omitted if the referenced package is
            locally scoped without an associated checksum.";
    }

    leaf-list supported-optional-feature {
        type pkg-types:scoped-feature;
        description
            "Lists all optional module features that are also
            supported by the server when implementing the package.

            This list SHOULD exclude any features in the
            'mandatory-feature' list for the package, or any included
            package.

            The full set of features supported by the server for this
            schema is the union of this list and all
            'mandatory-feature' lists for the package and all
            included packages. This is equivalent to the information
            provided via the 'feature' leaf list in YANG library.

            Features are identified using
            '<module-name>:<feature-name>';
    }

```

```

    }

    description
        "Describes which package the schema directly relates to, if
        any.";
    }
}

```

```

augment "/yanglib:yang-library/yanglib:module-set/yanglib:module" {

  description
    "Add 'replaced-revision' and 'checksum' to implemented module
    definitions.";

  leaf-list replaces-revision {
    type rev:revision-date-or-label;
    description
      "Gives the revision of an module (implemented or import-only)
      defined in an included package that is replaced by this
      implemented module revision.

      Only used for YANG package definitions";
  }

  leaf checksum {
    type pkg-types:sha-256-hash;
    description
      "The SHA-256 hash calculated on the textual module
      definition, represented as a hexadecimal string.";
  }
}

augment
  "/yanglib:yang-library/yanglib:module-set/" +
  "yanglib:module/yanglib:submodule" {

  description
    "Add 'checksum' to implemented modules' submodule
    definitions.";

  leaf checksum {
    type pkg-types:sha-256-hash;
    description
      "The SHA-256 hash calculated on the textual submodule
      definition, represented as a hexadecimal string.";
  }
}

```

```

augment "/yanglib:yang-library/yanglib:module-set/" +

```

```

        "yanglib:import-only-module" {

description
    "Add 'replaces-revision' and 'checksum' to import-only-module
    definitions";

    leaf-list replaces-revision {
        type rev:revision-date-or-label;
        description
            "Gives the revision of an import-only-module defined in an
            imported package that is replaced by this import-only-module
            revision.

            Only used for YANG package definitions";
    }

    leaf checksum {
        type pkg-types:sha-256-hash;
        description
            "The SHA-256 hash calculated on the textual module
            definition, represented as a hexadecimal string.";
    }
}

augment "/yanglib:yang-library/yanglib:module-set/" +
    "yanglib:import-only-module/yanglib:submodule" {

description
    "Add 'checksum' to import-only-modules' submodule
    definitions.";

    leaf checksum {
        type pkg-types:sha-256-hash;
        description
            "The SHA-256 hash calculated on the textual submodule
            definition, represented as a hexadecimal string.";
    }
}
}
<CODE ENDS>

```

```

<CODE BEGINS> file "ietf-yang-inst-data-pkg@2019-09-11.yang"
module ietf-yang-inst-data-pkg {
    yang-version 1.1;
    namespace "urn:ietf:params:xml:ns:yang:ietf-yang-inst-data-pkg";

```

```
prefix yid-pkg;

import ietf-yang-revisions {
  prefix rev;
  reference "XXXX: Updated YANG Module Revision Handling";
}

import ietf-yang-package-types {
  prefix pkg-types;
  rev:revision-or-derived 0.1.0;
  reference "RFC XXX: YANG Schema Versioning.";
}

import ietf-yang-structure-ext {
  prefix sx;
  reference "RFC XXX: YANG Data Structure Extensions.";
}

import ietf-yang-instance-data {
  prefix yid;
  reference "RFC XXX: YANG Instance Data File Format.";
}

import ietf-inet-types {
  prefix inet;
  reference "RFC 6991: Common YANG Data Types.";
}

organization
  "IETF NETMOD (Network Modeling) Working Group";

contact
  "WG Web:    <http://tools.ietf.org/wg/netmod/>
   WG List:   <mailto:netmod@ietf.org>

   Author:    Rob Wilton
               <mailto:rwilton@cisco.com>";

description
  "The module augments ietf-yang-instance-data to allow package
   definitions to be used to define schema in YANG instance data
   documents.

   Copyright (c) 2019 IETF Trust and the persons identified as
   authors of the code. All rights reserved."
```

to the license terms contained in, the Simplified BSD License set forth in [Section 4.c](#) of the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>).

This version of this YANG module is part of RFC XXXX; see the RFC itself for full legal notices.

The key words '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](#) ([RFC 2119](#)) ([RFC 8174](#)) when, and only when, they appear in all capitals, as shown here.";

```
// RFC Ed.: update the date below with the date of RFC publication
// and remove this note.
// RFC Ed.: replace XXXX with actual RFC number and remove this
// note.
revision 2019-09-11 {
  rev:revision-label 0.1.0;
  description
    "Initial revision";
  reference
    "RFC XXXX: YANG Packages";
}

/*
 * Augmentations
 */

sx:augment-structure
  "/yid:instance-data-set/yid:content-schema-spec" {
    description
      "Add package reference to instance data set schema
      specification";
    case pkg-schema {
      container pkg-schema {
        leaf pkg-schema {
          type pkg-types:pkg-identifier;
        }
      }
    }
  }
```

```

    mandatory true;
    description
      "The package definition that defines the schema for this
       file.";
  }
  leaf checksum {
    type pkg-types:sha-256-hash;
    description
      "The SHA-256 hash of the package, calculated on

```

```

    the textual package definition, represented as a
    hexadecimal string.";
  }
  leaf-list location {
    type inet:uri;
    description
      "Contains a URL that represents where an instance data
       file for this YANG package can be found.

       This leaf will only be present if there is a URL
       available for retrieval of the schema for this entry.

       If multiple locations are provided, then the first
       location in the leaf-list MUST be the definitive
       location that uniquely identifies this package";
  }
}
}
}
}
<CODE ENDS>

```

## 11. Security Considerations

The YANG modules specified in this document defines a schema for data that is accessed by network management protocols such as NETCONF [[RFC6241](#)] or RESTCONF [[RFC8040](#)]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [[RFC6242](#)]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [[RFC5246](#)].

The NETCONF access control model [[RFC6536](#)] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

Similarly to YANG library [[I-D.ietf-netconf-rfc7895bis](#)], some of the readable data nodes in these YANG modules may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes.

One additional key different to YANG library, is that the 'ietf-yang-package' YANG module defines a schema to allow YANG packages to be defined in YANG instance data documents, that are outside the security controls of the network management protocols. Hence, it is

important to also consider controlling access to these package instance data documents to restrict access to sensitive information. SHA-256 checksums are used to ensure the integrity of YANG package definitions, imported modules, and sub-modules.

As per the YANG library security considerations, the module, revision and version information in YANG packages may help an attacker identify the server capabilities and server implementations with known bugs since the set of YANG modules supported by a server may reveal the kind of device and the manufacturer of the device. Server vulnerabilities may be specific to particular modules, module revisions, module features, or even module deviations. For example, if a particular operation on a particular data node is known to cause a server to crash or significantly degrade device performance, then the YANG packages information will help an attacker identify server implementations with such a defect, in order to launch a denial-of-service attack on the device.

## [12.](#) IANA Considerations

It is expected that a central registry of standard YANG package definitions is required to support this solution.

It is unclear whether an IANA registry is also required to manage specific package versions. It is highly desirable to have a specific

canonical location, under IETF control, where the definitive YANG package versions can be obtained from.

This document requests IANA to registers a URI in the "IETF XML Registry" [[RFC3688](#)]. Following the format in [RFC 3688](#), the following registrations are requested.

URI: urn:ietf:params:xml:ns:yang:ietf-yang-package-types.yang  
Registrant Contact: The IESG.  
XML: N/A, the requested URI is an XML namespace.

URI: urn:ietf:params:xml:ns:yang:ietf-yang-package.yang  
Registrant Contact: The IESG.  
XML: N/A, the requested URI is an XML namespace.

URI: urn:ietf:params:xml:ns:yang:ietf-yl-packages.yang  
Registrant Contact: The IESG.  
XML: N/A, the requested URI is an XML namespace.

This document requests that the following YANG modules are added in the "YANG Module Names" registry [[RFC6020](#)]:

Name: ietf-yang-package-types.yang

Namespace: urn:ietf:params:xml:ns:yang:ietf-yang-package-  
types.yang  
Prefix: pkg-types  
Reference: RFC XXXX

Name: ietf-yang-package.yang  
Namespace: urn:ietf:params:xml:ns:yang:ietf-yang-package.yang  
Prefix: pkg  
Reference: RFC XXXX

Name: ietf-yl-packages.yang  
Namespace: urn:ietf:params:xml:ns:yang:ietf-yl-packages.yang  
Prefix: yl-pkg  
Reference: RFC XXXX

### [13.](#) Open Questions/Issues

All issues, along with the draft text, are currently being tracked at

## 14. Acknowledgements

Feedback helping shape this document has kindly been provided by Andy Bierman, Joe Clarke, James Cumming, Mahesh Jethanandani, Balazs Lengyel, Ladislav Lhotka, Jason Sterne, and Reshad Rahman.

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#### [Appendix A](#). Tree output for ietf-yang-library with package augmentations

Complete tree output for ietf-yang-library with package augmentations.

```
module: ietf-yang-library
  +--ro yang-library
  |   +--ro module-set* [name]
  |   |   +--ro name string
  |   |   +--ro module* [name]
  |   |   |   +--ro name yang:yang-identifier
  |   |   |   +--ro revision? revision-identifier
  |   |   |   +--ro namespace inet:uri
  |   |   |   +--ro location* inet:uri
  |   |   |   +--ro submodule* [name]
  |   |   |   |   +--ro name yang:yang-identifier
  |   |   |   |   +--ro revision? revision-identifier
  |   |   |   |   +--ro location* inet:uri
  |   |   |   |   +--ro yl-pkg:checksum? pkg-types:sha-256-hash
  |   |   |   +--ro feature* yang:yang-identifier
  |   |   |   +--ro deviation* -> ../../module/name
  |   |   |   +--ro yl-pkg:replaces-revision*
  |   |   |   |   yanglib:revision-identifier
  |   |   |   +--ro yl-pkg:checksum? pkg-types:sha-256-hash
  |   |   +--ro import-only-module* [name revision]
  |   |   |   +--ro name yang:yang-identifier
  |   |   |   +--ro revision union
  |   |   |   +--ro namespace inet:uri
  |   |   |   +--ro location* inet:uri
  |   |   +--ro submodule* [name]
  |   |   |   +--ro name yang:yang-identifier
```

| | | +--ro revision? revision-identifier

Wilton

Expires April 25, 2020

[Page 45]

Internet-Draft

YANG Packages

October 2019

```
| | | +--ro location* inet:uri
| | | +--ro pkg:checksum? pkg-types:sha-256-hash
| | | +--ro yl-pkg:replaces-revision*
| | | | yanglib:revision-identifier
| | | +--ro yl-pkg:checksum? pkg-types:sha-256-hash
| +--ro schema* [name]
| | +--ro name string
| | +--ro module-set* -> ../../module-set/name
| | +--ro yl-pkg:package
| | | +--ro yl-pkg:name?
| | | | -> /yanglib:yang-library/package/name
| | | +--ro yl-pkg:version? leafref
| | | +--ro yl-pkg:supported-feature* pkg-types:scoped-feature
| +--ro datastore* [name]
| | +--ro name ds:datastore-ref
| | +--ro schema -> ../../schema/name
| +--ro content-id string
| +--ro yl-pkg:package* [name version]
| | +--ro yl-pkg:name yang:yang-identifier
| | +--ro yl-pkg:version rev:revision-label
| | +--ro yl-pkg:timestamp? yang:date-and-time
| | +--ro yl-pkg:organization? string
| | +--ro yl-pkg:contact? string
| | +--ro yl-pkg:description? string
| | +--ro yl-pkg:reference? string
| | +--ro yl-pkg:complete? boolean
| | +--ro yl-pkg:location* inet:uri
| | +--ro yl-pkg:local? boolean
| | +--ro yl-pkg:previous-version? yang-sem-ver
| | +--ro yl-pkg:nbc-changes? boolean
| | +--ro yl-pkg:tag* tags:tag
| | +--ro yl-pkg:mandatory-feature* string
| | +--ro yl-pkg:included-package* [name version]
| | | +--ro yl-pkg:name yang:yang-identifier
| | | +--ro yl-pkg:version rev:revision-label
| | | +--ro yl-pkg:replaces-version* rev:revision-label
| | | +--ro yl-pkg:nbc-modified? boolean
| | | +--ro yl-pkg:location* inet:uri
| | | +--ro yl-pkg:checksum? string
| +--ro yl-pkg:module-set*
```

```

|      |      -> /yanglib:yang-library/module-set/name
|      +--ro yl-pkg:checksum?                        pkg-types:sha-256-hash
x--ro modules-state
  x--ro module-set-id      string
  x--ro module* [name revision]
    x--ro name              yang:yang-identifier
    x--ro revision          union
    +--ro schema?           inet:uri

```

```

x--ro namespace            inet:uri
x--ro feature*             yang:yang-identifier
x--ro deviation* [name revision]
|  x--ro name              yang:yang-identifier
|  x--ro revision          union
x--ro conformance-type     enumeration
x--ro submodule* [name revision]
  x--ro name              yang:yang-identifier
  x--ro revision          union
  +--ro schema?           inet:uri

```

#### notifications:

```

+---n yang-library-update
|  +--ro content-id      -> /yang-library/content-id
x---n yang-library-change
  x--ro module-set-id    -> /modules-state/module-set-id

```

## [Appendix B](#). Examples

This section provides various examples of YANG packages, and as such this text is non-normative. The purpose of the examples is to only illustrate the file format of YANG packages, and how package dependencies work. It does not imply that such packages will be defined by IETF, or which modules would be included in those packages even if they were defined. For brevity, the examples exclude namespace declarations, and use a shortened URL of "tiny.cc/ietf-yang" as a replacement for "https://raw.githubusercontent.com/YangModels/yang/master/standard/ietf/RFC".

### [B.1](#). Example IETF Network Device YANG package

This section provides an instance data document example of an IETF Network Device YANG package formatted in JSON.

This example package is intended to represent the standard set of YANG modules, with import dependencies, to implement a basic network device without any dynamic routing or layer 2 services. E.g., it includes functionality such as system information, interface and basic IP configuration.

As for all YANG packages, all import dependencies are fully resolved. Because this example uses YANG modules that have been standardized before YANG semantic versioning, they modules are referenced by revision date rather than version number.

Wilton

Expires April 25, 2020

[Page 47]

---

Internet-Draft

YANG Packages

October 2019

```
<CODE BEGINS> file "example-ietf-network-device-pkg.json"
===== NOTE: '\' line wrapping per BCP XX (RFC XXXX) =====

{
  "ietf-yang-instance-data:instance-data-set": {
    "name": "example-ietf-network-device-pkg",
    "pkg-schema": {
      package: "ietf-yang-package-defn-pkg@0.1.0.json"
    },
    "description": "YANG package definition",
    "content-data": {
      "ietf-yang-package:yang-package": {
        "name": "example-ietf-network-device-pkg",
        "version": "1.1.2",
        "timestamp": "2018-12-13T17:00:00Z",
        "organization": "IETF NETMOD Working Group",
        "contact" : "WG Web:  <http://tools.ietf.org/wg/netmod/>, \
                    WG List: <mailto:netmod@ietf.org>",
        "description": "Example IETF network device YANG package.\
\
This package defines a small sample set of \
YANG modules that could represent the basic set of \
modules that a standard network device might be expected \
to support.",
        "reference": "XXX, draft-rwilton-netmod-yang-packages",
        "location": [ "file://example.org/yang/packages/"
```

```

ietf-network-device@v1.1.2.json" ],
"module": [
  {
    "name": "iana-crypt-hash",
    "revision": "2014-08-06",
    "location": [ "https://tiny.cc/ietf-yang/\
iana-crypt-hash%402014-08-06.yang" ],
    "checksum": "fa9fde408ddec2c16bf2c6b9e4c2f80b\
813a2f9e48c127016f3fa96da346e02d"
  },
  {
    "name": "ietf-system",
    "revision": "2014-08-06",
    "location": [ "https://tiny.cc/ietf-yang/\
ietf-system%402014-08-06.yang" ],
    "checksum": "8a692ee2521b4ffe87a88303a61a1038\
79ee26bff050c1b05a2027ae23205d3f"
  },
  {
    "name": "ietf-interfaces",
    "revision": "2018-02-20",
    "location": [ "https://tiny.cc/ietf-yang/\

```

```

ietf-interfaces%402018-02-20.yang" ],
"checksum": "f6faea9938f0341ed48fda93dba9a69a\
a32ee7142c463342efec3d38f4eb3621"
},
{
  "name": "ietf-netconf-acm",
  "revision": "2018-02-14",
  "location": [ "https://tiny.cc/ietf-yang/\
ietf-netconf-acm%402018-02-14.yang" ],
  "checksum": "e03f91317f9538a89296e99df3ff0c40\
03cdfea70bf517407643b3ec13c1ed25"
},
{
  "name": "ietf-key-chain",
  "revision": "2017-06-15",
  "location": [ "https://tiny.cc/ietf-yang/\
ietf-key-chain@2017-06-15.yang" ],
  "checksum": "6250705f59fc9ad786e8d74172ce90d5\
8deec437982cbca7922af40b3ae8107c"
}

```

```

    },
    {
      "name": "ietf-ip",
      "revision": "2018-02-22",
      "location": [ "https://tiny.cc/ietf-yang/\
                    ietf-ip%402018-02-22.yang" ],
      "checksum": "b624c84a66c128ae69ab107a5179ca8e\
                  20e693fb57dbe5cb56c3db2ebb18c894"
    }
  ],
  "import-only-module": [
    {
      "name": "ietf-yang-types",
      "revision": "2013-07-15",
      "location": [ "https://tiny.cc/ietf-yang/\
                    ietf-yang-types%402013-07-15.yang" ],
      "checksum": "a04cdcc875764a76e89b7a0200c6b9d8\
                  00b10713978093acda7840c7c2907c3f"
    },
    {
      "name": "ietf-inet-types",
      "revision": "2013-07-15",
      "location": [ "https://tiny.cc/ietf-yang/\
                    ietf-inet-types%402013-07-15.yang" ],
      "checksum": "12d98b0143a5ca5095b36420f9ebc1ff\
                  a61cfd2eaa850080244cadf01b86ddf9"
    }
  ]
}

```

```

    }
  }
}
<CODE ENDS>

```

## [B.2.](#) Example IETF Basic Routing YANG package

This section provides an instance data document example of a basic IETF Routing YANG package formatted in JSON.

This example package is intended to represent the standard set of

YANG modules, with import dependencies, that builds upon the example-ietf-network-device YANG package to add support for basic dynamic routing and ACLs.

As for all YANG packages, all import dependencies are fully resolved. Because this example uses YANG modules that have been standardized before YANG semantic versioning, they modules are referenced by revision date rather than version number. Locations have been excluded where they are not currently known, e.g., for YANG modules defined in IETF drafts. In a normal YANG package, locations would be expected to be provided for all YANG modules.

<CODE BEGINS> file "example-ietf-routing-pkg.json"  
===== NOTE: '\' line wrapping per BCP XX (RFC XXXX) =====

```
{
  "ietf-yang-instance-data:instance-data-set": {
    "name": "example-ietf-routing-pkg",
    "module": [ "ietf-yang-package@2019-09-11.yang" ],
    "description": "YANG package definition",
    "content-data": {
      "ietf-yang-package:yang-package": {
        "name": "example-ietf-routing",
        "version": "1.3.1",
        "timestamp": "2018-12-13T17:00:00Z",
        "description": "This package defines a small sample set of \
          IETF routing YANG modules that could represent the set of \
          IETF routing functionality that a basic IP network device \
          might be expected to support.",
        "reference": "XXX, draft-rwilton-netmod-yang-packages",
        "imported-packages": [
          {
            "name": "ietf-network-device",
            "version": "1.1.2",
            "location": [ "http://example.org/yang/packages/\
```

```
      "checksum": ""
    },
    ],
    "module": [
      "ietf-network-device@v1.1.2.json" ],
```

```

{
  "name": "ietf-routing",
  "revision": "2018-03-13",
  "location": [ "https://tiny.cc/ietf-yang/\
                ietf-routing@2018-03-13.yang" ],
  "checksum": ""
},
{
  "name": "ietf-ipv4-unicast-routing",
  "revision": "2018-03-13",
  "location": [ "https://tiny.cc/ietf-yang/\
                ietf-ipv4-unicast-routing@2018-03-13.yang" ],
  "checksum": ""
},
{
  "name": "ietf-ipv6-unicast-routing",
  "revision": "2018-03-13",
  "location": [ "https://tiny.cc/ietf-yang/\
                ietf-ipv6-unicast-routing@2018-03-13.yang" ],
  "checksum": ""
},
{
  "name": "ietf-isis",
  "revision": "2018-12-11",
  "location": [ "https://tiny.cc/ietf-yang/\
                " ],
  "checksum": ""
},
{
  "name": "ietf-interfaces-common",
  "revision": "2018-07-02",
  "location": [ "https://tiny.cc/ietf-yang/\
                " ],
  "checksum": ""
},
{
  "name": "ietf-if-l3-vlan",
  "revision": "2017-10-30",
  "location": [ "https://tiny.cc/ietf-yang/\
                " ],
  "checksum": ""
},
{

```

```

    "name": "ietf-routing-policy",
    "revision": "2018-10-19",
    "location": [ "https://tiny.cc/ietf-yang/\n" ],
    "checksum": ""
  },
  {
    "name": "ietf-bgp",
    "revision": "2018-05-09",
    "location": [ "https://tiny.cc/ietf-yang/\n" ],
    "checksum": ""
  },
  {
    "name": "ietf-access-control-list",
    "revision": "2018-11-06",
    "location": [ "https://tiny.cc/ietf-yang/\n" ],
    "checksum": ""
  }
],
"import-only-module": [
  {
    "name": "ietf-routing-types",
    "revision": "2017-12-04",
    "location": [ "https://tiny.cc/ietf-yang/\nietf-routing-types@2017-12-04.yang" ],
    "checksum": ""
  },
  {
    "name": "iana-routing-types",
    "revision": "2017-12-04",
    "location": [ "https://tiny.cc/ietf-yang/\niana-routing-types@2017-12-04.yang" ],
    "checksum": ""
  },
  {
    "name": "ietf-bgp-types",
    "revision": "2018-05-09",
    "location": [ "https://tiny.cc/ietf-yang/\n" ],
    "checksum": ""
  },
  {
    "name": "ietf-packet-fields",
    "revision": "2018-11-06",
    "location": [ "https://tiny.cc/ietf-yang/\n" ],

```

Internet-Draft

YANG Packages

October 2019

```
        "checksum": ""
      },
      {
        "name": "ietf-ethertypes",
        "revision": "2018-11-06",
        "location": [ "https://tiny.cc/ietf-yang/\n",
                      "  " ],
        "checksum": ""
      }
    ]
  }
}
}
<CODE ENDS>
```

### [B.3.](#) Package import conflict resolution example

This section provides an example of how a package can resolve conflicting module versions from imported packages.

In this example, YANG package 'example-3-pkg' imports both 'example-import-1' and 'example-import-2' packages. However, the two imported packages implement different versions of 'example-module-A' so the 'example-3-pkg' package selects version '1.2.3' to resolve the conflict. Similarly, for import-only modules, the 'example-3-pkg' package does not require both versions of example-types-module-C to be imported, so it indicates that it only imports revision '2018-11-26' and not '2018-01-01'.

```
{
  "ietf-yang-instance-data:instance-data-set": {
    "name": "example-import-1-pkg",
    "description": "First imported example package",
    "content-data": {
      "ietf-yang-package:yang-package": {
        "name": "example-import-1",
        "version": "1.0.0",
        "reference": "XXX, draft-rwilton-netmod-yang-packages",
        "revision-date": "2018-01-01",
```

```

"module": [
  {
    "name": "example-module-A",
    "version": "1.0.0"
  },
  {

```

```

    "name": "example-module-B",
    "version": "1.0.0"
  }
],
"import-only-module": [
  {
    "name": "example-types-module-C",
    "revision": "2018-01-01"
  },
  {
    "name": "example-types-module-D",
    "revision": "2018-01-01"
  }
]
}
}
}
}
{
  "ietf-yang-instance-data:instance-data-set": {
    "name": "example-import-2-pkg",
    "description": "Second imported example package",
    "content-data": {
      "ietf-yang-package:yang-package": {
        "name": "example-import-2",
        "version": "2.0.0",
        "reference": "XXX, draft-rwilton-netmod-yang-packages",
        "revision-date": "2018-11-26",
        "module": [
          {
            "name": "example-module-A",
            "version": "1.2.3"
          },
          {

```

```

        "name": "example-module-E",
        "version": "1.1.0"
    },
    ],
    "import-only-module": [
        {
            "name": "example-types-module-C",
            "revision": "2018-11-26"
        },
        {
            "name": "example-types-module-D",
            "revision": "2018-11-26"
        }
    ]
}

```

```

    ]
  }
}
}
{
  "ietf-yang-instance-data:instance-data-set": {
    "name": "example-3-pkg",
    "description": "Importing example package",
    "content-data": {
      "ietf-yang-package:yang-package": {
        "name": "example-3",
        "version": "1.0.0",
        "reference": "XXX, draft-rwilton-netmod-yang-packages",
        "revision-date": "2018-11-26",
        "included-package": [
          {
            "name": "example-import-1",
            "version": "1.0.0"
          },
          {
            "name": "example-import-2",
            "version": "2.0.0"
          }
        ],
        "module": [
          {

```

```

        "name": "example-module-A",
        "version": "1.2.3"
    },
    "import-only-module": [
        {
            "name": "example-types-module-C",
            "revision": "2018-11-26",
            "replaces-revision": [ "2018-01-01 " ]
        }
    ]
}
}
}
}
}

```

## [Appendix C](#). Possible alternative solutions

This section briefly describes some alternative solutions. It can be removed if this document is adopted as a WG draft.

### [C.1](#). Using module tags

Module tags have been suggested as an alternative solution, and indeed that can address some of the same requirements as YANG packages but not all of them.

Module tags can be used to group or organize YANG modules. However, this raises the question of where this tag information is stored. Module tags either require that the YANG module files themselves are updated with the module tag information (creating another versioning problem), or for the module tag information to be hosted elsewhere, perhaps in a centralized YANG Catalog, or in instance data documents similar to how YANG packages have been defined in this draft.

One of the principle aims of YANG packages is to be a versioned object that defines a precise set of YANG modules versions that work

together. Module tags cannot meet this aim without an explosion of module tags definitions (i.e. a separate module tag must be defined for each package version).

Module tags cannot support the hierarchical scheme to construct YANG schema that is proposed in this draft.

## C.2. Using YANG library

Another question is whether it is necessary to define new YANG modules to define YANG packages, and whether YANG library could just be reused in an instance data document. The use of YANG packages offers several benefits over just using YANG library:

1. Packages allow schema to be built in a hierarchical fashion. [\[I-D.ietf-netconf-rfc7895bis\]](#) only allows one layer of hierarchy (using module sets), and there must be no conflicts between module revisions in different module-sets.
2. Packages can be made available off the box, with a well defined unique name, avoiding the need for clients to download, and construct/check the entire YANG schema for each device. Instead they can rely on the named packages with secure checksums. YANG library's use of a 'content-id' is unique only to the device that generated them.

3. Packages may be versioned using a semantic versioning scheme, YANG library does not provide a schema level semantic version number.
4. For a YANG library instance data document to contain the necessary information, it probably needs both YANG library and various augmentations (e.g. to include each module's semantic version number), unless a new version of YANG library is defined containing this information. The module definition for a YANG package is specified to contain all of the necessary information to solve the problem without augmentations
5. YANG library is designed to publish information about the modules, datastores, and datastore schema used by a server. The

information required to construct an off box schema is not precisely the same, and hence the definitions might deviate from each other over time.

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