Information Model for Wavelength Switched Optical Networks (WSONs) with
                        Impairments Validation
                    draft-ietf-ccamp-wson-iv-info-12

Abstract

   This document defines an information model to support Impairment-
   Aware (IA) Routing and Wavelength Assignment (RWA) functionality.
   This information model extends the information model for impairment-
   free RWA process in WSON to facilitate computation of paths where
   optical impairment constraints need to considered.

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Table of Contents

1. Introduction

In the context of Wavelength Switched Optical Network (WSON),
[RFC6163] describes the basic framework for a GMPLS and PCE-based
Routing and Wavelength Assignment (RWA) control plane. The

associated information model [RFC7446] defines information/parameters
required by an RWA process without optical impairment considerations.

There are cases of WSON where optical impairments play a significant
role and are considered as important constraints. The framework
document [RFC6566] defines the problem scope and related control
plane architectural options for the Impairment Aware RWA (IA-RWA)
operation. Options include different combinations of Impairment
Validation (IV) and RWA functions in term of different combination of
control plane functions (i.e., PCE, Routing, Signaling).

A Control Plane with RWA-IA will not be able to solve the optical
impairment problem in a detailed and exhaustive way, however, it may
take advantage of some data plane knowledge to make better decisions
during its path computing phase. The final outcome will be a path,
instantiated through a wavelength in the data plane, that has a
"better chance" to work than that path were calculated without IA
information. "Better chance" means that path setup may still fail
and the GMPLS control plane will follow its usual procedures upon
errors and failures. A control plane will not replace a the network
design phase that remains a fundamental step for DWDM Optical
Networks. As the non-linear impairments which need to be considered
in the calculation of an optical path will be vendor-dependent, the
parameters considered in this document is not an exhaustive list.

This document provides an information model for the impairment aware
case to allow the impairment validation function implemented in the
control plane or enabled by control plane available information.
This model goes in addition to [RFC7446] and shall support any
control plane architectural option described by the framework
document (see sections 4.2 and 4.3 of [RFC6566]) where a set of
combinations of control plane functions vs. IV function is provided.

2. Definitions, Applicability and Properties

This section provides some concepts to help understand the model and
to make a clear separation from data plane definitions (ITU-T
recommendations). The first sub-section provides definitions while
the Applicability sections uses the defined definitions to scope this
document.

2.1. Definitions

o Computational Model / Optical Computational Model.
   Defined by ITU standard documents (e.g. [ITU.G680]). In this
   context we look for models able to compute optical impairments for
   a given lightpath.

   o Information Model.
      Defined by IETF (this document) and provides the set of
      information required by control plane to apply the Computational
      Model.

   o Level of Approximation.
      This concept refers to the Computational Model as it may compute
      optical impairment with a certain level of uncertainty. This
      level is generally not measured but [RFC6566] Section 4.1.1
      provides a rough classification about it.

   o Feasible Path.
      It is the output of the C-SPF with RWA-IV capability. It's an
      optical path that satisfies optical impairment constraints. The
      path, instantiated through wavelength(s), may actually work or not
      work depending of the level of approximation.

   o Existing Service Disruption.
      An effect known to optical network designers is the cross-
      interaction among spectrally adjacent wavelengths: an existing
      wavelength may experience increased BER due to the setup of an
      adjacent wavelength. Solving this problem is a typical optical
      network design activity. Just as an example, a simple solution is
      adding optical margins (e.g., additional OSNR), although complex
      and detailed methods exist.

   o DWDM Line Segments.
      [ITU.G680] provides definition and picture for the "Situation 1"
      DWDM Line segments: " Situation 1 - The optical path between two
      consecutive 3R regenerators is composed of DWDM line segments from
      a single vendor and OADMs and PXCs from another vendor". Document
      [RFC6566] Figure 1 shows an LSP composed by two DWDM line segments
      according to [ITU.G680] definition.

2.2. Applicability

   This document targets at Scenario C defined in [RFC6566] section
   4.1.1. as approximate impairment estimation. The Approximate
   concept refer to the fact that this Information Model covers
   information mainly provided by [ITU.G680] Computational Model.

   Computational models having no or little approximation, referred as
   IV-Detailed in the [RFC6566], currently does not exist in term of
   ITU-T recommendation. They generally deal with non-linear optical
   impairment and are usually vendor specific.

   The Information Model defined in this document does not speculate
   about the mathematical formulas used to fill up information model

parameters, hence it does not preclude changing the computational
model. At the same time, the authors do not believe this Information
Model is exhaustive and if necessary further documents will cover
additional models after they become available.

The result of RWA-IV process implementing this Information Model is a
path (and a wavelength in the data plane) that has better chance to
be feasible than if it was computed without any IV function. The
Existing Service Disruption, as per the definition above, would still
be a problem left to a network design phase.

2.3. Properties

An information model may have several attributes or properties that
need to be defined for each optical parameter made available to the
control plane. The properties will help to determine how the control
plane can deal with a specific impairment parameter, depending on
architectural options chosen within the overall impairment framework
[RFC6566]. In some case, properties value will help to identify the
level of approximation supported by the IV process.

o Time Dependency
   This identifies how an impairment parameter may vary with time.
   There could be cases where there is no time dependency, while in
   other cases there may be need of re-evaluation after a certain
   time. In this category, variations in impairments due to
   environmental factors such as those discussed in [ITU.GSUP47] are
   considered. In some cases, an impairment parameter that has time
   dependency may be considered as a constant for approximation. In
   this information model, we do neglect this property.

o Wavelength Dependency
   This property identifies if an impairment parameter can be
   considered as constant over all the wavelength spectrum of
   interest or not. Also in this case a detailed impairment
   evaluation might lead to consider the exact value while an
   approximation IV might take a constant value for all wavelengths.
   In this information model, we consider both case: dependency / no
   dependency on a specific wavelength. This property appears
   directly in the information model definitions and related
   encoding.

o Linearity
   As impairments are representation of physical effects, there are
   some that have a linear behaviour while other are non-linear.
   Linear approximation is in scope of Scenario C of [RFC6566].
   During the impairment validation process, this property implies
   that the optical effect (or quantity) satisfies the superposition

principle, thus a final result can be calculated by the sum of
each component. The linearity implies the additivity of optical
quantities considered during an impairment validation process.
The non-linear effects in general do not satisfy this property.
The information model presented in this document however, easily
allow introduction of non-linear optical effects with a linear
approximated contribution to the linear ones.

o Multi-Channel
   There are cases where a channel's impairments take different
   values depending on the aside wavelengths already in place, this
   is mostly due to non-linear impairments. The result would be a
   dependency among different LSPs sharing the same path. This
   information model do not consider this kind of property.

The following table summarise the above considerations where in the
first column reports the list of properties to be considered for each
optical parameter, while the second column states if this property is
taken into account or not by this information model.

```
+-----------------------+---------------------+
|       Property        | Info Model Awareness |
+-----------------------+---------------------+
|    Time Dependency    |         no          |
| Wavelength Dependency |         yes         |
|      Linearity        |         yes         |
|     Multi-channel     |         no          |
+-----------------------+---------------------+
```

Table 1: Optical Impairment Properties

3. ITU-T List of Optical Parameters

As stated by Section 2.2 this Information Model does not intend to be
exhaustive and targets an approximate computational model although
not precluding future evolutions towards more detailed or different
impairments estimation methods.

On the same line, ITU SG15/Q6 provides (through [LS78]) a list of
optical parameters with following observations:

(a) the problem of calculating the non-linear impairments in a
     multi-vendor environment is not solved. The transfer functions
     works only for the so called [ITU.G680] "Situation 1".

(b) The generated list of parameters is not exhaustive however
     provide a guideline for control plane optical impairment
     awareness.

In particular, [ITU.G680] contains many parameters that would be
required to estimate linear impairments. Some of the Computational
Models defined within [ITU.G680] requires parameters defined in other
documents like [ITU.G671]. The purpose of the list here below makes
this match between the two documents.

[ITU.G697] defines parameters can be monitored in an optical network.
This Information Model and associated encoding document will reuse
[ITU.G697] parameters identifiers and encoding for the purpose of
path computation.

The list of optical parameters starts from [ITU.G680] Section 9 which
provides the optical computational models for the following p:

G-1 OSNR.   Section 9.1

G-2 Chromatic Dispersion (CD).   Section 9.2

G-3 Polarization Mode Dispersion (PMD).   Section 9.3

G-4 Polarization Dependent Loss (PDL).   Section 9.3

In addition to the above, the following list of parameters has been
mentioned by [LS78]:

L-1   "Channel frequency range", [ITU.G671]. This parameter is part
      of the application code and encoded through Optical Interface
      Class as defined in [RFC7446].

L-2   "Modulation format and rate". This parameter is part of the
      application code and encoded through Optical Interface Class as
      defined in [RFC7446].

L-3   "Channel power". Required by G-1.

L-4   "Ripple". According to [ITU.G680], this parameter can be taken
      into account as additional OSNR penalty.

L-5   "Channel signal-spontaneous noise figure", [ITU.G680].
      Required by OSNR calculation (see G-1) above.

L-6   "Channel chromatic dispersion (for fibre segment or network
      element)". Already in G-2 above.

L-7   "Channel local chromatic dispersion (for a fibre segment)".
      Already in G-2 above (since consider both local and fiber
      dispersions).

   L-8   "Differential group delay (for a network element)", [ITU.G671].
          Required by G-3.

   L-9   "Polarisation mode dispersion (for a fibre segment)",
          [ITU.G650.2], [ITU.G680]. Defined above as G-3.

   L-10   "Polarization dependent loss (for a network element)",
          [ITU.G671] and [ITU.G680]. Defined above as G-4.

   L-11   "Reflectance".   From [ITU.G671] Section 3.2.2.37 is the ratio
          of reflected power Pr to incident power Pi at a given port of a
          passive component, for given conditions of spectral
          composition, polarization and geometrical distribution.
          Generally expressed in dB. Might be monitored in some critical
          cases. We neglect this effect as first approximation.

   L-12   "Channel Isolation". From [ITU.G671] Section 3.2.2.2 (Adjacent
          Channel Isolation) and Section 3.2.2.29 (Non Adjacent Channel
          Isolation). Document [ITU.GSUP39] provide the formula for
          calculation as channel cross-talk and measure it in dB. This
          parameterer shall be considered for path computation.

   L-13   "Channel extinction". From [ITU.G671] Section 3.2.2.9 needed
          for Interferometric Crosstalk. Document [ITU.GSUP39] has the
          formula for penalty computation. Unit of measurement is dB.

   L-14   "Attenuation coefficient (for a fibre segment)". Document
          [ITU.G650.1] Section 3.6.2. The unit of measure is dB. This
          is a typical link parameter (as associated to a fiber).

   L-15   "Non-linear coefficient (for a fibre segment)", [ITU.G650.2].
          Required for Non-Linear Optical Impairment Computational
          Models. Neglected by this document.

   The final list of parameters is G-1, G-2, G-3, G-4, L-3, L-4, L-5,
   L-8, L-12, L-13, L-14.

4. Background from WSON-RWA Information Model

   In this section we report terms already defined for the WSON-RWA
   (impairment free) as in [RFC7446] and [RFC7579]. The purpose is to
   provide essential information that will be reused or extended for the
   impairment case.

   In particular [RFC7446] Section 4.1 defines the ConnectivityMatrix
   and states that such matrix does not represent any particular
   internal blocking behaviour but indicates which input ports and
   wavelengths could possibly be connected to a particular output port.

```
<ConnectivityMatrix> ::= <MatrixID> <ConnType> <Matrix>
```

According to [RFC7579], this definition is further detailed as:

```
<ConnectivityMatrix> ::=
     <MatrixID> <ConnType> ((<LinkSet> <LinkSet>) ...)
```

This second formula highlights how the ConnectivityMatrix is built by pairs of LinkSet objects identifying the internal connectivity capability due to internal optical node constraint(s). It's essentially binary information and tell if a wavelength or a set of wavelengths can go from an input port to an output port.

As an additional note, ConnectivityMatrix belongs to node information, is uniquely identified by advertising node and is a static information. Dynamic information related to the actual state of connections is available through specific extension to link information.

The [RFC7446] introduces the concept of ResourceBlockInfo and ResourcePool for the WSON nodes. The resource block is a collection of resources behaving in the same way and having similar characteristics. The ResourceBlockInfo is defined as follow:

```
<ResourceBlockInfo> ::= <ResourceBlockSet> [<InputConstraints>]
     [<ProcessingCapabilities>] [<OutputConstraints>]
```

The usage of resource block and resource pool is an efficient way to model constrains within a WSON node.

5. Optical Impairment Information Model

The idea behind this document is to put optical impairment parameters into categories and extend the information model already defined for impairment-free WSONs. The three categories are:

o Node Information. The concept of connectivity matrix is reused and extended to introduce an impairment matrix, which represents the impairments suffered on the internal path between two ports. In addition, the concept of Resource Block is also reused and extended to provide an efficient representation of per-port impairment.

o Link Information representing impairment information related to a specific link or hop.

o Path Information representing the impairment information related to the whole path.

All the above three categories will make use of a generic container, the Impairment Vector, to transport optical impairment information.

This information model however will allow however to add additional parameters beyond the one defined by [ITU.G680] in order to support additional computational models. This mechanism could eventually applicable to both linear and non-linear parameters.

This information model makes the assumption that the each optical node in the network is able to provide the control plane protocols with its own parameter values. However, no assumption is made on how the optical nodes get those value information (e.g., internally computed, provisioned by a network management system, etc.). To this extent, the information model intentionally ignores all internal detailed parameters that are used by the formulas of the Optical Computational Model (i.e., "transfer function") and simply provides the object containers to carry results of the formulas.

5.1. The Optical Impairment Vector

Optical Impairment Vector (OIV) is defined as a list of optical parameters to be associated to a WSON node or a WSON link. It is defined as:

<OIV> ::= ([<LabelSet>] <OPTICAL_PARAM>) ...

The optional LabelSet object enables wavelength dependency property as per Table 1. LabelSet has its definition in [RFC7579].

OPTICAL_PARAM. This object represents an optical parameter. The Impairment vector can contain a set of parameters as identified by [ITU.G697] since those parameters match the terms of the linear impairments computational models provided by [ITU.G680]. This information model does not speculate about the set of parameters (since defined elsewhere, e.g. ITU-T), however it does not preclude extensions by adding new parameters.

5.2. Node Information

5.2.1. Impairment Matrix

Impairment matrix describes a list of the optical parameters that applies to a network element as a whole or ingress/egress port pairs of a network element. Wavelength dependency property of optical parameters is also considered.

ImpairmentMatrix ::= <MatrixID> <ConnType>
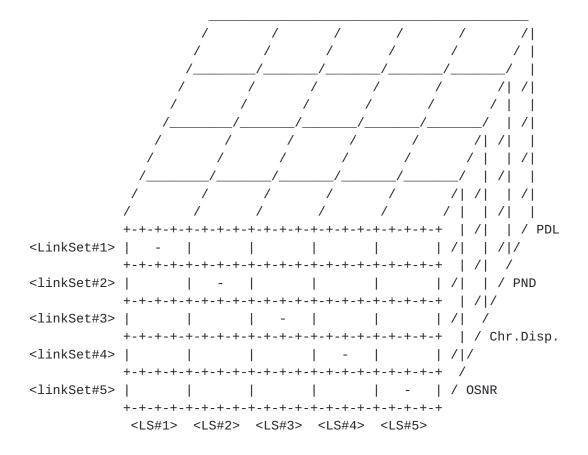   ((<LinkSet> <LinkSet> <OIV>) ...)

Where:

   MatrixID. This ID is a unique identifier for the matrix. It
   shall be unique in scope among connectivity matrices defined in
   [RFC7446] and impairment matrices defined here.

   ConnType. This number identifies the type of matrix and it shall
   be unique in scope with other values defined by impairment-free
   WSON documents.

   LinkSet. Same object definition and usage as [RFC7579]. The
   pairs of LinkSet identify one or more internal node constrain.

   OIV. The Optical Impairment Vector defined above.

The model can be represented as a multidimensional matrix shown in
the following picture

```
                         _____
                        /       /       /       /       /         /|
                       /       /       /       /       /        /  |
                     /_____/_____/_____/_____/_____/    |
                     /       /       /       /       /        /| /|
                    /       /       /       /       /        / |  |
                  /_____/_____/_____/_____/_____/  | /|
                  /       /       /       /       /        /| /|  |
                 /       /       /       /       /        / |  | /|
               /_____/_____/_____/_____/_____/  | /|  |
               /       /       /       /       /        /| /|  | /|
              /       /       /       /       /        / |  | /|  |
              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | /|  | / PDL
   <LinkSet#1> |   -  |      |      |       |       | /|  | /|/
              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | /|  /
   <linkSet#2> |      |  -   |      |       |       | /|  | / PND
              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | /|/
   <linkSet#3> |      |      |  -   |       |       | /|  /
              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  | / Chr.Disp.
   <linkSet#4> |      |      |      |  -    |       | /|/
              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+  /
   <linkSet#5> |      |      |      |       |  -    | / OSNR
              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
               <LS#1>  <LS#2>  <LS#3>  <LS#4>  <LS#5>
```

The connectivity matrix from [RFC7579] is only a two dimensional
matrix, containing only binary information, through the LinkSet

pairs. In this model, a third dimension is added by generalizing the
binary information through the Optical Impairment Vector associated
with each LinkSet pair. Optical parameters in the picture are
reported just as an example: proper list and encoding shall be
defined by other documents.

This representation shows the most general case however, the total
amount of information transported by control plane protocols can be
greatly reduced by proper encoding when the same set of values apply
to all LinkSet pairs.

5.2.2. Impairment Resource Block Information

This information model reuses the definition of Resource Block
Information adding the associated impairment vector.

```
ResourceBlockInfo ::= <ResourceBlockSet> [<InputConstraints>]
    [<ProcessingCapabilities>] [<OutputConstraints>] [<OIV>]
```

The object ResourceBlockInfo is than used as specified within
[RFC7446].

5.3. Link Information

For the list of optical parameters associated to the link, the same
approach used for the node-specific impairment information can be
applied. The link-specific impairment information is extended from
[RFC7446] as the following:

```
<DynamicLinkInfo> ::=  <LinkID> <AvailableLabels>
        [<SharedBackupLabels>] [<OIV>]
```

DynamicLinkInfo is already defined in [RFC7446] while OIV is the
Optical Impairment Vector is defined in the previous section.

5.4. Path Information

There are cases where the optical impairments can only be described
as a constrains on the overall end to end path. In such case, the
optical impairment and/or parameter, cannot be derived (using a
simple function) from the set of node / link contributions.

An equivalent case is the option reported by [RFC6566] on IV-
Candidate paths where, the control plane knows a list of optically
feasible paths so a new path setup can be selected among that list.
Independent from the protocols and functions combination (i.e. RWA
vs. Routing vs. PCE), the IV-Candidates imply a path property stating
that a path is optically feasible.

The concept of Optical Impairment Vector (OIV) might be used or
extended to report optical impairment information at path level
however this is case is letf for future studies.

6. Encoding Considerations

Details about encoding will be defined in a separate document
[I-D.ietf-ccamp-wson-iv-encode] however worth remembering that,
within [ITU.G697] Appending V, ITU already provides a guideline for
encoding some optical parameters.

In particular [ITU.G697] indicates that each parameter shall be
represented by a 32 bit floating point number.

Values for optical parameters are provided by optical node and it
could provide by direct measurement or from some internal computation
starting from indirect measurement. In such cases, it could be
useful to understand the variance associated with the value of the
optical parameter hence, the encoding shall provide the possibility
to include a variance as well.

This kind of information will enable IA-RWA process to make some
additional considerations on wavelength feasibility. [RFC6566]
 Section 4.1.3 reports some considerations regarding this degree of
confidence during the impairment validation process.

7. Control Plane Architectures

This section briefly describes how the definitions contained in this
information model will match the architectural options described by
[RFC6566]. This section does not suggest suggested any specific
protocol option.

The assumption is that WSON GMPLS extensions are available and
operational. To such extent, the WSON-RWA will provide the following
information through its path computation (and RWA process):

o The wavelengths connectivity, considering also the connectivity
   constraints limited by reconfigurable optics, and wavelengths
   availability.

o The interface compatibility at the physical level.

o The Optical-Elettro-Optical (OEO) availability within the network
   (and related physical interface compatibility). As already stated
   by the framework this information it's very important for
   impairment validation:

   A. If the IV functions fail (path optically infeasible), the path
       computation function may use an available OEO point to find a
       feasible path. In normally operated networks OEO are mainly
       uses to support optically unfeasible path than mere wavelength
       conversion.

   B. The OEO points reset the optical impairment information since
       a new light is generated.

7.1. IV-Centralized

   Centralized IV process is performed by a single entity (e.g. a PCE or
   other external entities). Given sufficient impairment information,
   it can either be used to provide a list of paths between two nodes,
   which are valid in terms of optical impairments. Alternatively, it
   can help validate whether a particular selected path and wavelength
   is feasible or not.

   Centralized IV functions requires exchange of impairment information
   to the entity performing the IV process from network nodes. This
   information exchange may requires implementation of this information
   model within an exsting protocol (i.e. routing procol vs PCEP vs BGP-
   LS vs others).

7.2. IV-Distributed

   Assuming the information model is implemented through a routing
   protocol, every node in the WSON network shall be able to perform an
   RWA-IV function.

   The signalling phase may provide additional checking as others
   traffic engineering parameters.

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10. IANA Considerations

   This document does not contain any IANA requirement.

11. Security Considerations

   This document defines an information model for impairments in optical
   networks. If such a model is put into use within a network it will
   by its nature contain details of the physical characteristics of an

optical network. Such information would need to be protected from
intentional or unintentional disclosure.

12. References

12.1. Normative References

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Appendix A. FAQ

A.1. Why the Application Code does not suffice for Optical Impairment Validation?

Application Codes are encoded within GMPLS WSON protocol through the
Optical Interface Class as defined in [RFC7446].

The purpose of the Application Code in RWA is simply to assess the
interface compatibility: same Application Code means that two
interfaces can have an LSP connecting the two.

Application Codes contain other information useful for IV process
(e.g., see the list of parameters) so they are required however
Computational Models requires more parameteres to assess the path
feasibility.

A.2. Are DWDM network multivendor?

According to [ITU.G680] "Situation 1" the DWDM line segments are
single are single vendor but an LSP can make use of different data
planes entities from different vendors. For example: DWDM interfaces
(represented in the control plane through the Optical Interface
Class) from a vendor and network elements described by Stutation 1
from another vendor.

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