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Information Model for Wavelength Switched Optical Networks (WSONs) with Impairments Validation

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Abstract

This document defines an information model to support Impairment-Aware (IA) Routing and Wavelength Assignment (RWA) function. This operation might be required in Wavelength Switched Optical Networks (WSON) that already support RWA and the information model defined here goes in addition and it is fully compatible with the already defined information model for impairment-free RWA process in WSON.

This information model shall support all control plane architectural options defined for WSON with impairment validation.

Status of This Memo

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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 [I-D.ietf-ccamp-rwa-info] defines all information/parameters required by an RWA process.

There are cases of WSON where optical impairments plays 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).

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 [I-D.ietf-ccamp-rwa-info] 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 concepts used along the document and to make a clear separation about what coming from data plane definitions (ITU-T G recommendations) and are taken as input for this Information Model. The first sub-section provides raw definitions while the Applicability sections reuses the defined concepts to scope this document.

2.1. Definitions

- Computational Model / Optical Computational Model.
  Defined by ITU standard documents. In this context we look for models able to compute optical impairments for a given lightpath.

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

- 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 network designers: this model does not replace by any means the optical network design phase. The Information Model applies to GMPLS context with the associated relationship between data plane(s) and control plane.

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.

- 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 [G.sup47] 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.

- 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.

- 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 definitive or exaustive.

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 [I-D.ietf-ccamp-rwa-info].

L-2   Modulation format and rate.
      This parameter is part of the application code and encoded through Optical Interface Class as defined in [I-D.ietf-ccamp-rwa-info].

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, ITU.G680]
Defined above as G-4.

L-11 Reflectance [ITU.G671].

L-12 Isolation [ITU.G671] and [ITU.GSUP39]

L-13 Channel extinction [ITU.G671] and [ITU.GSUP39].

L-14 Attenuation coefficient (for a fibre segment) [ITU.G650.1].

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-11, 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 [I-D.ietf-ccamp-rwa-info] and [I-D.ietf-ccamp-general-constraint-encode]. The purpose is to provide essential information that will be reused or extended for the impairment case.

In particular [I-D.ietf-ccamp-rwa-info] defines the connectivity matrix as the following:

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

According to [I-D.ietf-ccamp-general-constraint-encode], this definition is further detailed as:

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

This second formula highlights how the connectivity matrix 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, connectivity matrix belongs to node information and is purely static. Dynamic information related to the actual usage of the connections is available through specific extension to link information.

Furthermore [I-D.ietf-ccamp-rwa-info] define the resource block as follow:

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

Which is an efficient way to model constrains of a WSON node.

5. Optical Impairment Information Model

The idea behind this information model is to categorize the impairment parameters into three types 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 modelization 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 [I-D.ietf-ccamp-general-constraint-encode].

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 extentions 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 paramters 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 [I-D.ietf-ccamp-rwa-info] 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 [I-D.ietf-ccamp-general-constraint-encode]. 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 [I-D.ietf-ccamp-general-constraint-encode] 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 examples while details go into specific encoding draft [I-D.martinelli-ccamp-wson-iv-encode].

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.

[EDITOR NODE: first run of the information model does looks for generality not for optimizing the quantity of information. We'll deal with optimization in a further step.]

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 [I-D.ietf-ccamp-rwa-info].

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 [I-D.ietf-ccamp-rwa-info] as the following:

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

DynamicLinkInfo is already defined in [I-D.ietf-ccamp-rwa-info] while OIV is the Optical Impairment Vector is defined in the previous section.

5.4. Path Information

There are cases where the optical impariments can only be described as a contrains on the overall end to end path. In such case, the optical impariment 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.

```
<PathInfo> ::=  <OIV>
```

[EDITOR NOTE: section to be completed, especially to evaluate protocol implications. Likely resemble to RSVP ADSPEC].

6. Encoding Considerations

Details about encoding will be defined in a separate document [I-D.martinelli-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 parmater 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 defintions contained in this information model will match the architectural options described by [RFC6566].

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

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

- The interface compatibility at the physical level.

- 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). 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 feasiable or not. This requires distribution of impairment information to the entity performing the IV process.

This Informaton Model doesn't make any hypotesys on distribution method for optical parameters but only defines the essential build blocks. A centralized entity may get knowledge of required informaton through routing protocools or other mechanism such as BGP-LS.

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.

8. Acknowledgements

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9. IANA Considerations

This document does not contain any IANA requirement.

10. 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.

11. References

11.1. Normative References

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[RFC6163] Lee, Y., Bernstein, G., and W. Imajuku, "Framework for GMPLS and Path Computation Element (PCE) Control of Wavelength Switched Optical Networks (WSONs)", RFC 6163, April 2011.

[RFC6566] Lee, Y., Bernstein, G., Li, D., and G. Martinelli, "A Framework for the Control of Wavelength Switched Optical Networks (WSONs) with Impairments", RFC 6566, March 2012.

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 [I-D.ietf-ccamp-rwa-info].

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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