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

draft-martinelli-ccamp-wson-iv-info-02

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.

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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 problem scope and related control plane architectural options for the Impairment Aware Routing and Wavelength Assignment (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 it 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 control plane combinations of control plane functions vs. IV functions is provided.

1.1. Applicability

This document targets at Scenario C defined in [RFC6566] section 4.1.1., i.e., approximate impairment estimation. The usage of "Approximate" concept helps to clarify that a path resulting from a IV-RWA process are not guaranteed to work from an optical perspective however, has better chance to be feasible than other(s). Setting up the ligth-path, there is still a possibility to fail but this is an acceptable in term of GMPLS control plane.

The information model defined in this document strictly relates to a control plane information model hence it does not define any new Optical Computational Model. Optical Computational Models are defined by ITU-T, [ITU.G680] defines transfer functions for some linear optical parameters while there's no general optical computational model for non-linear effects. This information model uses the available optical computational model as a reference, and identify GMPLS WSON control plane extensions to allow IV functions to perform its task.

Following here above considerations, scope of this information model is to provide a generic mechanism so will easily support additional impairment parameters and/or additional optical computational models.

2. Properties of an Impairment Information Model

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 behavior 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 does 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.

- 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 cosider this kind of property.

The following table summarize 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. Background from WSON 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.

4. 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:

- Node Information. The concept of connectivity matrix is reused and extended to introduce an impairment matrix.

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

- 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.

In term of optical parameters, this document is not to rephrase content from [ITU.G680] but only provide necessary building blocks that allow the IA-RWA process to apply the specific Optical Computational Model (i.e. transfer functions). Section 9 of [ITU.G680] defines the optical computational models and provides information to calculate the following optical parameters:

- OSNR. Section 9.1

- Optical Power. As per Section 9.1, required by Optical Computation Model for OSNR calculation.

- Chromatic Dispersion (CD). Section 9.2

- Polarization Mode Dispersion (PMD). Section 9.3

- Polarization Dependent Loss (PDL). Section 9.3

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 node gets 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.

4.1. 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.

4.2. Node Information

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.]

4.3. 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.

4.4. 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].

5. 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.

As an additional consideration, actual values for each optical parameter are provided by each optical node and it could provide by direct measurement or from some internal computation starting from indirect measurement. In any case the encoding shall provide the possibility to associate a variance with the parameter. This information will enable the function implementing 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.

6. 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):

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.

6.1. 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.

[EDITOR NOTE: to be completed]

6.2. IV-Distributed

For the distributed IV process, common computational models are needed together with the information model defined in this document. Computational models for the optical impairments are defined by ITU standard body. The currently available computation models are reported in [ITU.G680] and only cover the linear impairment case. This does not require the distribution of impairment information since they can be collected hop-by-hop using a control plane signaling protocol.

[EDITOR NOTE: to be completed]

7. Acknowledgements

TBD

8. Contributing Authors

This document was the collective work of several authors. The text and content of this document was contributed by the editors and the co-authors listed below (the contact information for the editors appears in appropriate section and is not repeated below):

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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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Appendix A. G.680 Essential information

TBD if we need some info instead of reading [ITU.G680]

[Xian's note]: I thought about listing paramters to show different categories. but it seems to contradict to the idea of providing a general enough information model. Any suggestions?

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