GMPLS perspectives to control WSON

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Introduction

• The topic of GMPLS extensions to control Wavelength Switched Optical Networks was in the spotlight in 2001.
• There were activities inside “IPO Working Group”, but also CCAMP Working Group with several internet drafts covering physical impairments, photonic and hybrid architectures, protocol extensions propositions, …
• Year 2007 has been the theater of a major regain of interest by vendors and (operators) for the control of Wavelength Switched Optical Networks by GMPLS.
What is a WSON and which are its specificities? 1/2

- Wavelength Switched Optical Networks (WSON) consist in photonic devices enabling the realization of optical circuit connections, exploiting appropriately limited O-E-O conversion resources.
  - Induced signal continuity brings technological challenges to control plane protocols:
    - Wavelength assignment
    - Physical limits of the transmission reach
    - Wavelength transparency to signal (encoding and bandwidth)
What is a WSON and which are its specificities 2/2

- Specificities:
  - Wavelength assignment correspond to the selection of the wavelength or a limited set of wavelengths along the connection path and hence the selection of re-coloration points.
  - Transmission reach limitations occur in widespread network where long distance LSP may need O-E-O regeneration at some intermediate points to ensure satisfactory signal quality.
    - Transparency islands do not consist in a proper network design.
  - Wavelength is transparent to signal, then to encodings and bit-rate but that may not be utterly true.

- Most of these aspects are linked to the resource assignment usually named Routing and Wavelength Assignment (RWA) in a WSON context
THE Issue: Routing and Wavelength Assignment

- Strategies to perform RWA can be separated in two kinds
  - Centralized RWA at ingress node (or using a PCE)
    - Alike a NMS functioning
  - Ingress Routing followed by distributed Wavelength Assignment
    - Alike a usual GMPLS CP functioning

- Both these strategies have strong and different standardization impacts. Following drafts contribute to one or the other strategy.

<table>
<thead>
<tr>
<th>Draft Title</th>
<th>RWA strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Centralized”</td>
</tr>
<tr>
<td>Framework for GMPLS and PCE Control of WSON</td>
<td>X</td>
</tr>
<tr>
<td>RWA Information for WSON</td>
<td>X</td>
</tr>
<tr>
<td>Signaling Extensions for WSON</td>
<td>X</td>
</tr>
<tr>
<td>GMPLS Signaling Extensions for Optical Impairment Aware Light-path Setup</td>
<td>X</td>
</tr>
<tr>
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</tr>
<tr>
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<td>X</td>
</tr>
<tr>
<td>PCEP Requirements and Extensions for the support of WSON</td>
<td>X</td>
</tr>
</tbody>
</table>
Criteria determining a RWA strategy

**Why choosing Distributed Wavelength Assignment?**

- In line with GMPLS principles
  - Scalability
  - Likely to raise a consensus at IETF
- Complexity is managed locally
  - Resources availability is known by the local switch fabric with utmost accuracy
- Is the solution optimal?
  - Missing the global picture when computing the path is seen as preventing optimality of resource allocation
  - Can optimality be increased with distributed strategies?
- Proprietary differentiator can be held in provisioning strategies
  - Solutions to enhance optimality are kept as proprietary strategies

**Why choosing Centralized Wavelength Assignment?**

- Network-wide detailed view is the best way to achieve optimal solution
- Heavy flooding of information regarding Wavelength Availability in links
  - Heavy standardization work that has to reach a consensus
  - Dynamicity issue: a unique competing allocation breaks the full path
- Heavy flooding of information regarding resources constraints
  - Flood connectivity constraints inside nodes (once again standardization)
Problematic 1: Wavelength is transparent to signal

Current Opaque LSAs advertise several bandwidth related parameters

In WSON different bit-rate (e.g.: 2,5Gb/s; 10Gb/s; 40Gb/s) can coexist:

- A wavelength channel on a link is a resource transparent to bit-rate

In WDM networks bandwidth may not be best suited to describe link capacity

Hence the number of wavelengths “multiplexable” may be more meaningful to describe the TE-parameters of a WDM link than the Maximum_Bandwidth.
Problematic 1: Wavelength is transparent to signal

A wavelength channel on a link is a resource transparent to bit-rate

Moreover in WSON different signal modulation (RZ, NRZ) can coexist:

Is a wavelength channel a resource transparent to modulation?

The pair (modulation; bit-rate) of the optical signal determines the spectral width of the channel, hence the usable ITU grid

The number of optical channels “multiplexable” in a WDM link depends both on the modulation and bit-rate of the channels.

Are current bandwidth based TE-parameters adapted for route computation?

The effective “bandwidth” resource in a WDM link is the total addressable spectral width of the link.
Problematic 2: Distributing information for centralized RWA

The challenge: convey the amount of information to the RWA algorithm with enough dynamicity…

- Needed information is not limited to Wavelength availability inside links:
  - Huge bunch of information is needed see table below (from quoted drafts):
    - draft-bernstein-ccamp-wson-info-02
    - draft-lee-pce-wson-routing-wavelength-01
    - draft-li-ccamp-wson-igp-eval-00

<table>
<thead>
<tr>
<th>Objects</th>
<th>Description</th>
<th>Information dynamicity</th>
<th>Related to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity_Matrix</td>
<td>Describe connectivity of WSON elements ((R-)OADM, OXC, OLT…)</td>
<td>Static</td>
<td>Node</td>
</tr>
<tr>
<td>Port_Wavelength.Restrictions</td>
<td>Specifies (in-)compatibility between wavelengths and network element ports</td>
<td>Static ?</td>
<td>Node</td>
</tr>
<tr>
<td>WDM_Link_Characterization</td>
<td>Specifies spectral features of a WDM link</td>
<td>Static</td>
<td>Link</td>
</tr>
<tr>
<td>Laser_Transmitter.Range</td>
<td>Specifies transponders tunability range</td>
<td>Static</td>
<td>Link ?</td>
</tr>
<tr>
<td>Wavelength_Converter_Characterization</td>
<td>Specifies features of regenerators: modulation characteristics and acceptable wavelengths ranges (in and out)</td>
<td>Static</td>
<td>Node</td>
</tr>
<tr>
<td>Wavelength_Availability</td>
<td>Advertises wavelengths availability of a link/fiber</td>
<td>Dynamic</td>
<td>Link</td>
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- Converters availability should also be dynamically conveyed

** Raises some questions:**
  - Is IGP appropriate? Is it scalable?
Problematic 3: Wavelength assignment in a distributed manner

Is it possible today to find a lightpath in a distributed manner?
• Wavelength continuity can be insured by label swapping
• Label_Set reduction mechanism enables the selection of a transparent wavelength
• Converters available in intermediate nodes can widen the Label_Set
• If no possible wavelength assignment exists on the selected route a crank-back mechanism can demand another trial on an alternative spatial route

Are there needs for improvement?
– For WSON embedding multiple bit-rates and signal encodings:
  to select converters it is mandatory to know LSP characteristics (e.g. encoding)
  • draft-bernstein-ccamp-wson-signaling-01 embeds this in SENDER_TSpec object
– Optimality is questioned:
  • Regarding usage of converters: marking labels with preferences enables an enlightened choice (using fewest converters on that route)
    – Same draft proposes Wavelength_Set_Metric compatible with that
Problematic 4: Checking the physical feasibility of a LSP

Checking a LSP Bit Error Rate (BER): reasonable step when setting the LSP

– Either to compute a physically feasible route, chose the proper wavelength or impose regeneration along the LSP (and localize this regeneration)
– Transmission engineers work on prediction functions giving the BER of a LSP as a function of physical parameters describing the path (or the LSP). (see reference)
– This prediction function usually depends on:
  • **Signal encoding**: Bit-rate, modulation format, FEC
  • **Chosen route and optionally chosen wavelength** (more accurate prediction)

A proper solution in a **distributed WA strategy** context would:

– Provide physical aware parameters (at the link level) to route computation algorithm
– Optionally increase the accuracy of these parameters by adjusting their value to each wavelength proposed through signaling

A proper solution in a **centralized WA strategy** context would have to balance between:

– Limiting its accuracy of prediction with link only parameters (agnostic to wavelength)
– Maintaining of whole network physical knowledge at the wavelength granularity
Problematic 4: Checking the physical feasibility of a LSP

Which parameters:

– Regarding their nature:
  • Either parameters physically describing the links
    – Then used as inputs for the prediction function
    – Standardization people are more likely to agree on a set of such parameters
    – Many parameters are needed per link
  • Or parameters describing the BER penalty of the links
    – Outputs of the prediction function (doubt to raise a consensus for that)
    – A parameter per link and per (encoding, bit-rate) pair

– Regarding their usage:
  • Used through routing:
    – Avoid dynamic parameters, which value should be updated (risk of burdening the flood of info)
  • Used through signaling:
    – Higher dynamicity parameters can be used as collection is performed through signaling, then intrinsically up-to-date.
How does IETF address the physical feasibility of LSPs?

**GMPLS** today does not embed any mechanism to handle it.

**GMPLS Signaling Extensions for Optical Impairment Aware Light-path Setup** (draft-martinelli-ccamp-optical-imp-signaling-00):
- Proposes a solution to collect physical parameters through signaling
  - intrinsically differentiating wavelengths compliance to transmission.
- Collected parameters are updatable on a hop-by-hop strategy
- BER computation is cleverly let out of the scope of this draft, which limits itself to provide an important tool to perform WA and regeneration localization.

This draft brings value to GMPLS as it integrates physical impairments.
A complementary approach helping route computation would enrich current initiatives.
Problematic 5: Determining the localization of a regeneration point in a LSP

When computing a route for a new connection
- No path may be physically feasible
  => **Regeneration is needed**

The challenge is to get a solution providing:
- Regeneration points knowledge (mandatory to compute paths)
  => **Need to advertise regeneration points**
- Advertisement must hold details of regenerators capabilities and availabilities
  - Point-less computing a route relying on a regenerator which cannot handle the modulation format used by the signal or which is already used, or which cannot be cross-connected between the wished input and output ports.

**GMPLS today does not provide a mechanism for that. What about drafts?**
- Drafts suggest the use of IGP to convey this information (converters and regenerators can benefits from the same protocols objects as both are O-E-O equipments)
  - draft-bernstein-ccamp-wson-info-02
  - draft-li-ccamp-wson-igp-eval-00

- **Would require, in addition, the availability and “cross-connectability” information**
- Distributed and Centralized RWA have approximately the same needs in that context
Primarily, it is mandatory to provide a solution to take into considerations the physical reach limitations of optical channels.

Secondly, there are two envisioned approaches for LSP reservation, that we can stigmatize as follows:

1. Extending GMPLS information system with a finer grain vision of the network
2. Sticking to GMPLS based-principles behold by scalability constraints

Main arguments for the first approach take their roots in the fear of not reaching optimality with the second one.

We consider that the second approach offers following advantages:

- **The complexity is deported into local processes** (like switching controller)
- Avoids the need to incorporate in standards current and future data-plane architectures, thus speed standardization work.
- Information held locally is always up-to-date

On the whole it seems simpler to enhance current GMPLS mechanisms, with some tailored features that would ease the setup of LSP in WSON, and prepare data-plane inter-op.
References

- **Papers**

- **Drafts**

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<td>Generalized Labels of Lambda-Switching Capable LSR</td>
</tr>
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Questions?

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