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A MILP Model to Solve the Problem of Loading Balance of Routing and Wavelength Assignment for Optical Transport Networks
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Abstract

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This documentary provides a model of Mixed-Integer Linear Programming to solve the problem of load balancing needed by routing and wavelength assignment (RWA) process in optical transport networks.

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1. Introduction

With the development of communication technology, business demand for network bandwidth is also increasing.

The routing algorithm is usually based on the shortest path algorithm (Dijkstra), and it will make the most of the businesses concentrate in a small number of links, drain seriously on the resources link, creating an unbalanced load on the network. Network load imbalances in turn affect the subsequent establishment of the business route, leading to higher rates of occlusion and reducing network performance.

In order to achieve network load balancing, we propose an MILP model. In this paper, we consider the load balancing of the OTN and use the mixed-integer linear program (MILP) to solve the RWA problem. We find the existed MILP models can't have a perfect solution without considering load balancing. This model is applicable in the optical transport networks. The OTN networks have a lot of advantages over the WDM networks. It can transport a variety of client signals transparently, like 10GE/40GE/100GE etc. Flexible & efficient grooming of any rate services can be achieved with OTN switcher. Also service adjustments can be completed remotely by NMS.

In this Model the network node has no wavelength conversion capability for static RWA problem. Our objective is to achieve load balancing of the optical transport networks, and improve network throughput.

1.1. Terminology

RWA: Routing and Wavelength Assignment.

Wavelength Conversion: The process of converting an information bearing optical signal centered at a given wavelength to one with "equivalent" content centered at a different wavelength. Wavelength conversion can be implemented via an optical-electronic-optical (OEO) process or via a strictly optical process.

OTN: Optical Transport Networks.

2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [RFC2119].

3. Overview

In dynamic optical transport network, research on the resource optimization and constraint-based routing problem mainly includes the following aspects:

(1)path selection and wavelength assignment problem in optical layer.

(2)Constraint-based routing problem under dynamic business in Multi-layer network.

(3)resource optimization problem under dynamic business in the multi-layer network.

3.1. RWA Problem

Optical layer path selection and wavelength assignment problem, which is called RWA (Routing and Wavelength Assignment, routing and wavelength assignment) problem, is mainly caused by the require of consistency and constraints of wavelength in the optical fiber link.

Optical layer routing based on Dijkstra algorithm is usually started by the different parameters chosen as consideration to select the least costly path, common optical path selection algorithms are mainly fixed routing algorithm, fixed alternate routing algorithm, adaptive routing algorithm and adaptive shortest alternate routing algorithm.

Wavelength assignment algorithm is usually based on heuristic algorithms, aiming to obtain the minimum blocking rate under a certain number of wavelengths. There are several common wavelength assignment algorithms such as randomly assigned wavelength method, first-fit, the minimum application method, the most widely used method and the lightest load method. The core problem of dynamic business constraints routing issue is the method for electrical and optical layers combined to find proper routes.

3.2. Optimization of Network Resources

We need to choose from all of the implementation designs for logical topology of the network to make the best performance of packet service delivery program. For small-scale networks we can use mixed integer linear programming (Mixed Integer Linear Programming, MILP); to optimize the design of large-scale networks, we often use heuristic algorithm. In this paper we focus on the MILP method to solve the RWA problem in optical transport networks considering the load balancing of the network.

4. Previous Work

The existing MILP model to solve RWA problem is relatively simple, which cannot be a good solution without considering load balancing in optical transport network, so we improve the existing MILP-based mathematical model, and propose an improved MILP model which can be used under the condition of certain blocking rate with considering load balancing in the optical transport network.

4.1. Definition

MILP: Mixed integer linear programming (Mixed-Integer Linear Programming, MILP) is a class of special mathematical program in which all or part of the variables are restricted to be integer values and the constraints are linear. It brings in the mixed integer based on the ILP.

ILP: An integer programming problem is a mathematical optimization or feasibility program in which some or all of the variables are restricted to be integers. In many settings the term refers to integer linear programming (ILP), in which the objective function and the constraints (other than the integer constraints) are linear.

The Static RWA problem can be attributed to a class of programming problems, of which the mathematical description of the problem has been fully discussed for. The basic idea of the algorithm is: write a column of equations for the objective to be optimized write a column of constraint equations solve the linear program.

4.2. Definition

In the absence of wavelength convertors, an optical path would occupy the same wavelength on all fiber links through which it passes. This is called the wavelength-continuity constraint in wavelength-routed networks. Given a set of optical paths, we need to route and assign a wavelength to each of them; this is called the routing and wavelength

assignment (RWA) problem. The RWA problem can be formulated as a mixed-integer linear program.

The RWA problem, without the wavelength continuity constraint, can be formulated as a multi-commodity flow problem with integer link flows. This corresponds to an integer linear program (ILP) with the objective function being to minimize the flow in each link. Let t_sd denote the traffic (in terms of an optical path) from source s to destination d. We consider at most one optical path from a source to a destination, hence t_sd = 1 if there is an optical path from s to d, otherwise t_sd = 0. We do not consider bidirectional optical paths, i.e. t_sd = 1 does not necessarily imply t_sd = 1. Let F_sdij denote the traffic (in terms of number of optical paths) flowing from Source s to destination d on link ij. The linear Programming formulation is

o Minimize: Such that F_max >= SUM_s,d [F_sdij],for any i and j.

```
o                                         -t_sd,  s=j
   SUM_s,d [F_sdij] - SUM_s,d [F_sdjk] = { t_sd,   d=j}
                                           0,otherwise
```

Since this model only solves the problem of RWA for the network, the constraint equation column does not include the wavelength continuity constraint equation. If we need to solve the routing problem and wavelength problem at the same time, we need to add an equation, which lead to the complexity increasing greatly for the question.

5. A MILP Model to Solve the Problem of Loading Balance of RWA for OTN

With the development of communication technology, business demand for network bandwidth is also increasing. And because the routing algorithms are usually based on the shortest path algorithm, thus making the most of the businesses concentrate in a small number of links. Such lead to a serious drain on the resources for these links, creating an unbalanced network load. Network load imbalances in turn affect the subsequent establishment of the traffic route, resulting in the increase of blocking rate and reduce of network performance. In order to achieve network loading balance, we propose this MILP model. Nodes used in the model for the OTN network have no wavelength conversion capability for static RWA problem. Our aim is to achieve loading balance of the network and improve network throughput.

5.1. Parameters

o G=(V,E) Undirected graph topology for physical network

o SUM_s,d [F_sd] The sum of F_sd for all valid s and d

o [A c B] A belongs to B

o A /= B A is not equal to B

o V   Collection of nodes in the network, V={v1,v2,...,vn}

o E   Collection of the fiber links in the network, E {e1,e2,...,em}

o T   Collection of the traffics, T={t1,t2,...,ti};
each traffic t corresponds to a set of parameters
(S_t,D_t,B_t)

o S_t   The source node of the traffic, [t c T]

o D_t   The destination node of the traffic, [t c T]

o B_t   The bandwidth occupied by the traffic, [t c T]

o L   Collection of available wavelengths, L={l1,l2,...,lw}

o W   The maximum number of available wavelengths, W=|L|

o B   The maximum bandwidth of the available wavelength L

o w(i) Collection of the adjacent edges of the node vi, [vi c V]

o K   The order of the ODU, K={1,2,3,4}

5.2. Variables

(1)The rate of the ODU_k is shown as follows:

```
          2.5; k=1
ODU_k = { 10;  k=2 ; (Gbps)
          40;  k=3
          100; k=4
```

(2)The order of the ODU is determined by the following formula:

```
      1; 0 < B_t <= 2.5
k = { 2; 2.5 <= B_t <= 10 ; [t c T]
      3; 10 < B_t <= 2.5
      4; 40 < B_t <= 100
```

(3)The parameter X_t represents the status of the connection establishing:

```
     1, If the traffic t is established successfully
X_t={0,                 Otherwise                  ; [t c T]
```

(4)The parameter X_t(e) represents whether the traffic t passes link e:

```
        1, If the traffic t passes link e
X_t(e)={0,           Otherwise           ;[t c T]
```

(5) The parameter X_t(e,l) represents whether the traffic t occupies the wavelength l on link e:

```
          1,If the traffic t occupies the wavelength
X_t(e,l)={  l on link e                             ;[t c T],[l c L]
          0,            Otherwise
```

(6) The parameter X_t(e,l,k) represents whether the traffic t occupies ODU_k on wavelength l of link e:

```
             1, If the traffic t occupies ODU_k
X_t(e,l,k)={    on wavelength l of link e      ;[t c T],[l c L],[k c K]
             0,          Otherwise
```

5.3. Objective Function

o Objective Function: min R=S

o S: The maximum utilization of links in the network.

o Make the R to its minimum, to achieve the loading balance for the network

5.4. Constraints

(1)The total bandwidth occupied by all traffics on each available wavelength of any link must be smaller than the maximum bandwidth of the wavelength

SUM_t SUM_k [X_t(e,l,k)ODU_k] <= B;[t c T], [t c T], [l c L]

(2)To prevent self-loop: for the source node or the destination node, there should be only one adjacent link to transmit traffic;

SUM_[e c w(vi)] [X_t(e)] = 1; [t c T],[vi c {s_t,d_t}]

for the node else, the adjacent links should be no more than 2, and once the node receives a traffic from one link, there should be another link to send the traffic again:

```
SUM_[e c w(vi)] [X_t(e)] <= 2;  [t c T],[vi c V\{s_t,d_t}]

SUM_([e' c w(vi)],e'/=e) [X_t(e')] >= X_t(e);[t c T],[e c w(vi)],
                                            [vi c V\{s_t,d_t }]
```

(3)Traffic in the network can only occupies one wavelength and one ODU_k:

```
SUM_l [X_t(e,l)] <= X_t(e);  [e c E],[l c L]

SUM_l SUM_k [X_t(e,l,k)] <= X_t(e);  [e c E],[l c L]
```

All of the links transmitting the traffic should provide the same wavelength and ODU_k:

```
SUM_[e c w(vi)] SUM_l [X_t(e,l)] = 1;  [t c T],[l c L],
                                      [v_i c {s_t,d_t}]

SUM_[e c w(vi)] [X_t(e,l)] <= 2;     [t c T],[l c L],
                                    [vi c V\{s_t,d_t}]

SUM_([e' c w(vi)],e'/=e [X_t(e',l)]) >= X_t(e,l); [t c T],[l c L],
                                             [vi c V\{s_t,d_t}]
```

(4)The source node and the destination node of the same traffic should use the same wavelength:

```
SUM_[e c w(s_t)] [X_t(e,l)] = SUM_[e' c w(d_t)] [X_t(e',l)];
                                            [t c T],[l c L]
```

The source node and the intermediate node should use the same wavelength:

```
SUM_[e c w(s_t)] [X_t(e,l)] + SUM_eEw(d_t) [X_t(e,l)] >=
 SUM_[e c w(vi)][X_t(e,l)];   [t c T],[e c E],[l c L],
                              [vi c V\{s_t,d_t}]

SUM_[e c w(vi)] [X_t(e,l)] <= 2;  [t c T],[e c E],[l c L],
                                  [vi c V\{s_t,d_t}]
```

To measure the average degree between resource utilizations of all links, we need two integer variables:

o R_e represents the total bandwidth occupied by all traffics on link e:

R_e= SUM_t SUM_l SUM_k [X_t(e,l,k)ODU_k]; [e c E]

o S represents the maximum of the resource utilizations of all links:

S >= R_e/(WB); [e c E]

6. Formal Syntax

The following syntax specification uses the augmented Backus-Naur Form (BNF) as described in RFC-2234 [RFC2234].

7. Security Considerations

This document discussed an information model for RWA computation in OTN. Such a model is very similar from a security standpoint of the information that can be currently conveyed via GMPLS routing protocols. Such information includes network topology, link state and current utilization, and well as the capabilities of switches and routers within the network. As such this information should be protected from disclosure to unintended recipients. In addition, the intentional modification of this information can significantly affect network operations, particularly due to the large capacity of the optical infrastructure to be controlled.

8. IANA Considerations

This informational document does not make any requests for IANA action.

9. Conclusions

<Add any conclusions>

10. References

10.1. Normative References

[1] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[2] Crocker, D. and Overell, P.(Editors), "Augmented BNF for Syntax Specifications: ABNF", RFC 2234, Internet Mail Consortium and Demon Internet Ltd., November 1997.

[3] Banerjee, D.; Mukherjee, B., "A practical approach for routing and wavelength assignment in large wavelength-routed optical networks," Selected Areas in Communications, IEEE Journal on , vol.14, no.5, pp.903,908, Jun 1996.

[4] Jaumard, B.; Meyer, C.; Thiongane, B.; Yu, Xiao, "ILP formulations and optimal solutions for the RWA problem," Global Telecommunications Conference, 2004. GLOBECOM '04. IEEE , vol.3, no., pp.1918,1924 Vol.3, 29 Nov.-3 Dec. 2004

[5] Barpanda, R.S.; Sahoo, B.; Turuk, A.K.; Majhi, B., "Solving large problem instances of the RWA problem using Genetic Algorithms," Industrial and Information Systems (ICIIS), 2010 International Conference on , vol., no., pp.41,46, July 29 2010-Aug. 1 2010.

[6] Krishnaswamy, R.M.; Sivarajan, K.N., "Algorithms for routing and wavelength assignment based on solutions of LP-relaxations," Communications Letters, IEEE , vol.5, no.10, pp.435,437, Oct. 2001.

[7] Wang, X.; Brandt-Pearce, M.; Subramaniam, S., "Dynamic grooming and RWA in translucent optical networks using a time-slotted ILP," Global Communications Conference (GLOBECOM), 2012 IEEE , vol., no., pp.2996,3001, 3-7 Dec. 2012.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2234] Crocker, D. and Overell, P.(Editors), "Augmented BNF for Syntax Specifications: ABNF", RFC 2234, Internet Mail Consortium and Demon Internet Ltd., November 1997.

10.2. Informative References

[8] Faber, T., Touch, J. and W. Yue, "The TIME-WAIT state in TCP and Its Effect on Busy Servers", Proc. Infocom 1999 pp. 1573-1583.

[Fab1999] Faber, T., Touch, J. and W. Yue, "The TIME-WAIT state in TCP and Its Effect on Busy Servers", Proc. Infocom 1999 pp. 1573-1583.

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