RSA and research suggestions in EONs

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Outlines

1. RSA overview
2. Model and solutions
3. Some aspects in my study group
4. Some research proposals

1. RSA overview

RSA: routing and spectrum assignment (allocation)

- ✓ The methods are used to solve RSA:
  - Solve routing and spectrum assignment jointly
  - Divide RSA into the two separated problems, routing and spectrum assignment, and solve each one independently
- ✓ Increase resource usage ratio by grooming either in electronic domain or optical one.

- ✓ According to the given or input parameters of each connection request, if network resource are assigned , we need to find a optimized scheme of resource allocation. It is impossible to decide whether such a scheme is optimal or not in the feasible space for the most cases.
- ✓ Generally speaking, RSA can be roughly classified into four aspects: the requested service source, network resource scenarios, problem modeling, and its solution methods.

Properties of a connection request

✓ Dynamics：

- **Static:** Requested connection arrives at t=0,never leaves or service duration is infinite, ∞.
- **Dynamic:** Both arrival moment and service duration are random.
- **Semi-dynamic** (scheduled): For arrival moment and service duration, at the least one parameter is given in advance (there are three cases).

Properties of a connection request

- **Number of source and destination users/connections：**
  - unicast (1: 1)
  - unicast (1: n)
  - broadcast (1: all)
  - Mix or combination of those listed above
  - hybrid-cast (m : n)

✓ Bandwidth granularity：

- Absolute transmission bandwidth, [a, b] Kbps, Mbps, Gbps
- Absolute bandwidth, [a, b]-OC1, (-λs) (OC1=51.84Mbps)
- Relative bandwidth,[a, b]-FSs, (-λs) (Frequency Slots), it became absolute transmission speed if the absolute bandwidth of each carrier and modulation are given.

Topology of physical networks

- **Single (domain)：**
  - Small ,6 nodes
  - Middle ,e.g., NSFnet with 14 nodes and 21 links
  - large, e.g., ARPAnet,CHINAnet
  - Created randomly
- **Multi-domain：**
  - Consist of several networks that are heterogeneous and/or homogeneous, and are usually located in horizontal direction, e.g., access network + core networks.

✓ Multi-layer：

- Consists of networks that are heterogeneous and are usually located in vertical direction ,e.g., SDH/OTN/Fiber

2.1 RSA Modelling

- **Modeling types:**
  - Integer Linear Programming (ILP)
  - Mixed ILP (MILP)

- **Modeling components**
  - Subject to (S.T.): spectrum continuity constraint, spectrum contiguity constraint, non-overlapping constraint
  - bandwidth capacity constraint, guard band constraint, etc.
  - …

Objective

- **Single objective:**

Minimizing number of wavelengths and FSs, crosstalk in multi-core fiber, blocking, CPEX, OPEX, energy consumption, etc.

Maximizing operator's income.

- **Multi-objective :**

There are more than two objectives which are diversionary or conflict to some extent, e.g. , Minimizing the connection blocking and crosstalk among multi-core.

2.2 RSA solution methods

- **Can be classified to two kinds:**
  - **Mathematical Programming:**

    We can use programming solution tools like Lingo and IBM CPLEX) in small topology of static service.
  - **Heuristics:**

    We can find optimal solutions in partial space or approximately optimized solutions. These algorithms have low complexity and are very suitable to dynamic service.

- **Heuristic algorithms consist of three types**
  - **Traditional heuristics：**

    It is based on intuition or experience, we usually do not know the gap between the feasible solution and optimal one, e.g., min hops with k routes.
  - **Meta-heuristics:**

    It is based on the features of natural phenomena or the biological beings , we refer to as this kind to intelligent algorithms.
  - **Hybrid-heuristics：**

    Mix the traditional heuristic algorithm and intelligent one, especially, combination of different algorithms.

Traditional algorithms

- ***k-SP(k shortest paths)***
- **weights of metric:** For all candidate paths, we select the best one by hops of links, link bandwidth usage ratio, suitability, or combination of factors with normalization.
- **Tabu:** disenabling some parameters, link had been used to prevent loop route.
- **Combination of weights：** key links for whole network or weighted links, multiplication of requested bandwidth and min. hops along the path

Meta-heuristics

- **Evolutionary：**
  - GA: Genetic Algorithm
  - Co-Evolution (Co-Ev, cooperative)： interactions among several populations
  - Diff-Evolution： the present population is composed of a parent population and one that is the differentiation of two parent populations
  - ACO: ant colony optimization
  - PSO: particle swarm optimization
  - SA: simulated annealing
  -

meta-heuristics

- **Artificial intelligent (AI) algorithms:**
  - artificial bees
  - artificial fishes
  - artificial neural networks
  - artificial immune system
  - …

Hybrid intelligent algorithm

- **Mix the traditional- and intelligent- algorithm**
- **Examples of hybrid GA:**
  - Add GA with adaptation , changing some parameters in GA, e.g., methods of crossover and mutation, and their probabilities
  - GA plus immune
  - GA plus Tabu
  - …
- **GA plus ACO:** we use ACO to get the improved initial population
- **GA plus SA**
- **…**

3. Some works in our group

- Heuristics:
  - 1) Dr. YANG Fan
  - 2) I and Mr. ding ZE (a Ph. D candidate): integrated weighting, key links, etc.
- Intelligent algorithms (implemented and ongoing):
  - GA for various scenarios
  - ACO with static and dynamic requests
  - Co-Ev with single- and multi-objective , blocking and crosstalk in multi-core fiber networks

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Projects:

- Novel intelligent algorithms and formalization of resource optimization in hybrid elastic optical networks, national Nature Science Foundation of China (NSFC), No. 61572391, 2016.1-2019.12
- Key tech. on Tbps transport equipment with 100G/40G interface (subproject), ministry of Industry and Information Tech. (MIIT) , 2012.1-2015.12

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- Outputs：
  - Paper: Published nearly 40 papers which are indexed by SCI and EI, most of them are written in Chinese
  - Patents : We had more than 20 patent applications, and got 4 Licensed or authorized Patents

4. Research suggestions

- On the basis of all aspects or components that are related to writing a paper and just introduced, I asked me how can we make some aspects unusual? The general idea is mix, hybrid, diversity, etc. It means the mix of some related components with new ideas.
- Here are some examples, the ideas are from the discussion between teacher and students, the implementation in following examples are made by my M.E. students Mr. JIA Wenbin, Mr. WANG Kai, and Mr. ZAI botao.

- Example No.1
  - For dynamic service and at arrival moment of each request, can we consider the future information or factors affecting the path selection, such as the traffic of each link ?
  - We use Back-propagation neural networks (BPNNs) to predict the traffic in the future, and propose an algorithm of Minimum Comprehensive Weight with Prediction (MCWP).
  - Here , we review MCWP using an integrated weights, some more details are found in [1] .

[1] Wenbin Jia,Zhanqi Xu,Zhe Ding, Kai Wang. An Efficient Routing and Spectrum Assignment Algorithm Using Prediction for Elastic Optical Networks. International Conference on Information System and Artificial Intelligence (ISAI). June 2016, Hong Kong, China. ---- **PPT is available if interested**

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- Procedure of MCWP:
  - Step1: Select *k paths with Shortest path First* for each source/destination pair. Use BPCN to predict the traffic varying of all links;
  - Step2:, Calculate the Time Coincidence Ratio, denoted by (A/B) , i.e., here A denotes the sum of time coincidence related to the new arrival request for all links along one of the *k* candidate paths; while B represents the time duration of the new request is multiplied by the number of the related links which have time coincidence or overlapping with the new request.
  - Step3: Use *TCR*, the normalized hops and the spectrum usage of the candidate path, as the Integrated Weight (IW). Select the path that has the least IW .

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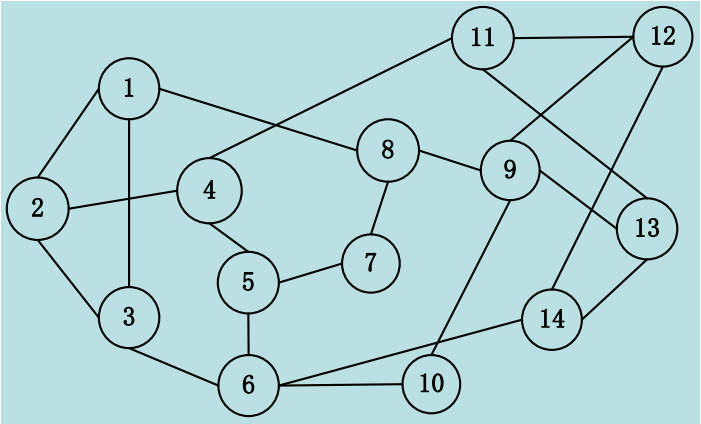
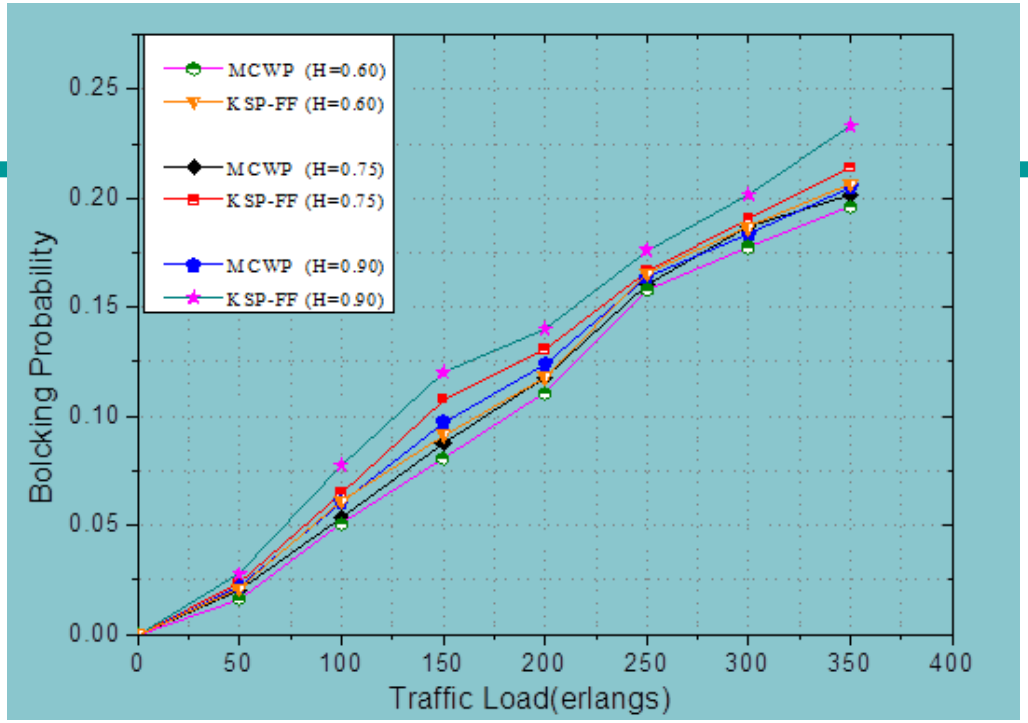
Simulation results



- Per-link capacity: **320 frequency slots**
- Width of a frequency slot: **12.5GHz**
- (s, d) pair is **uniformly** selected from all possible source-destination pairs
- Self-similar traffic
- The requested frequency slots is randomly generated with a uniform distribution within [1,6] frequency slots
- **5 candidate paths** for each connection, **1 guard frequency slot**



This figure gives the blocking probability between KSP-FF (first fit) and MCWP. It shows that blocking probability of MCWP is lower than that of KSP-FF. Instead of Poisson stream, we use a self-similar traffic, and we explain later.

The primary reason for this experimental result is that the traditional RSA algorithms only consider the current spectrum situation and do not forecast future information to reserve more resource for burst connections. Moreover, MCWP could comprehensively consider the time domain overlap, spectrum utilization and path length.

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- Example No.2
  - Can we use new service models that are more practical than those used usually?
  - For dynamic service, arrival of each request is usually Poisson process. However, we use self-similar model in which internet service is depicted or described more “exactly”, this fact had been verified by many studies.

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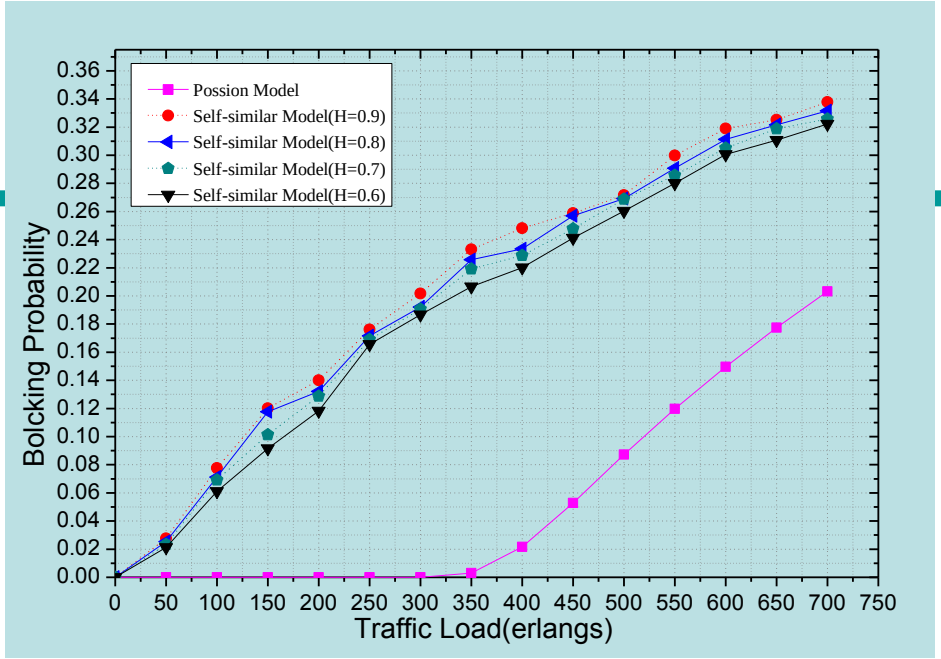
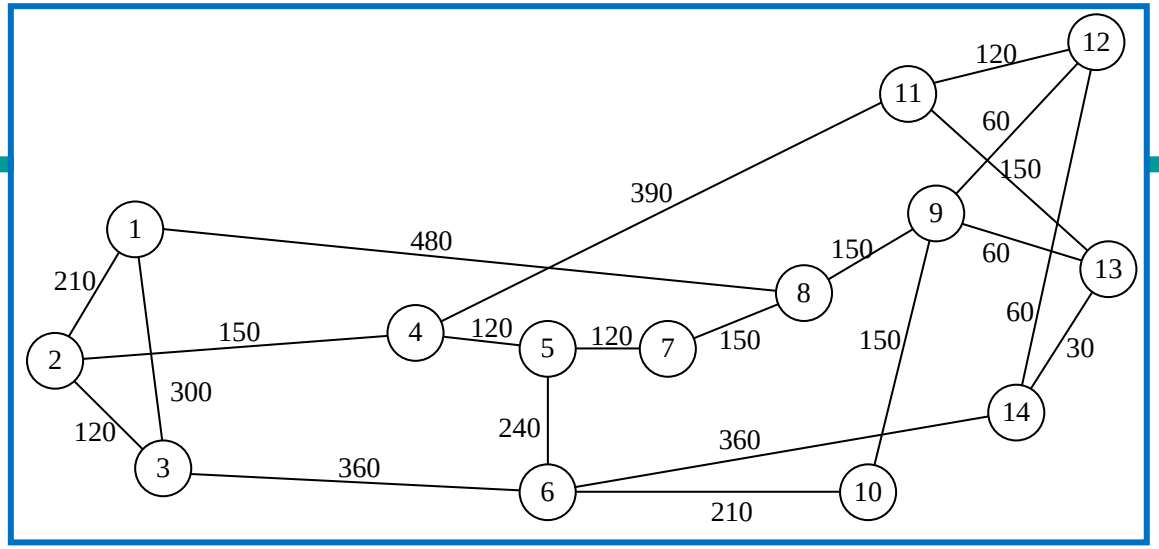


In this Fig., we compare the blocking probability between Poisson model and self-similar model. Due to the bursty of requests, the blocking probability of self-similar traffic increases linearly compared to that of Poisson traffic when the total traffic is less than 350 erlangs. When the H parameter is larger, the blocking probability keeps higher for self-similar traffic itself.

- Example No.3—(in “multi-”aspects)
  (1)multi-objective
  - Can we use multi-objective for multi-core EON?
    Since multi-Core EON has special crosstalk problem.
  - Based on multi-objective evolutionary algorithm with decomposition (MOEAD), we proposed two objective for multi-Core EON, and have made a partial progress.



(1) Simulation parameters

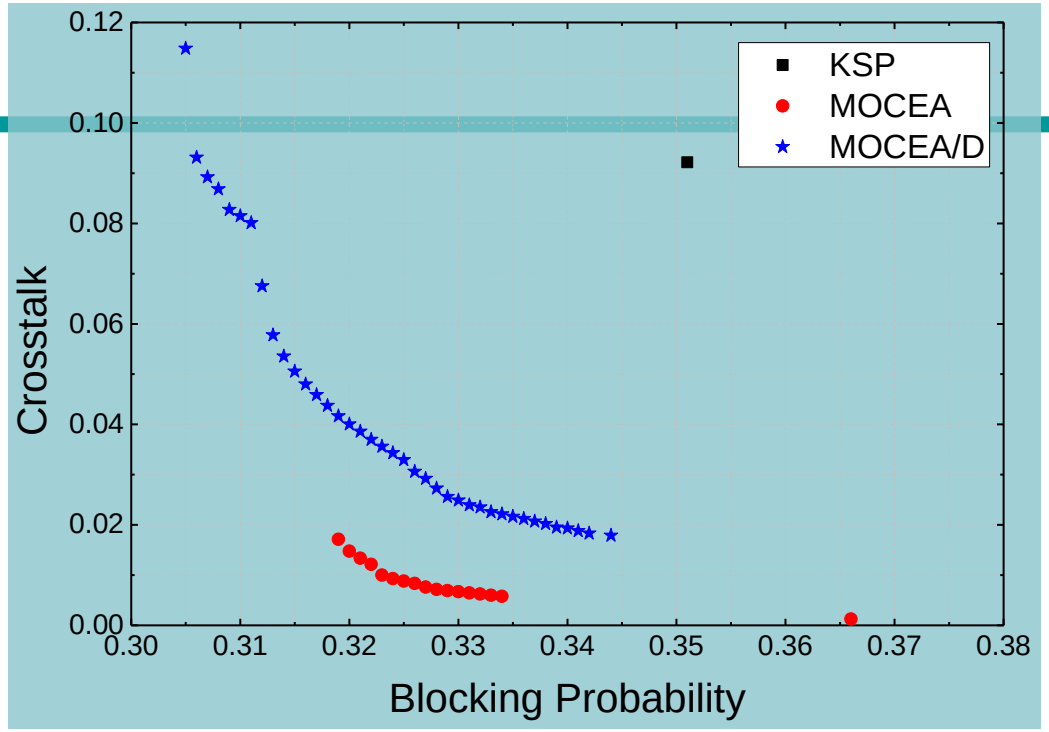
- Core number / link: 7
- Capacity / core: 80 frequency slots
- Request capacity of traffic: uniformly within [1,10] frequency slots
- Number of connection requests : 1000
- 5 candidate paths for each connection
- 1 guard frequency slot

(2) MOCEA (will be renamed)

- Population size: 100
- Crossover probability: 0.9
- Mutation probability: 0.5

(3) MOCEA/D (will be renamed)

- Population size: 100
- crossover probability: 0.5 (differential evolutionary)
- mutation probability: 0.3



- The solutions of MOCEA and MOCEA/D dominate that of KSP .
- Compared with MOCEA, MOCEA/D has better uniformity and wider distribution space.
- The convergence of MOCEA is better than that of MOCEA/D .

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- Example No.3—(in “multi-”aspects)
  (3)multi-resource
  - For bandwidth, store and computation resource, we use assignment each one or two types. If all three types of resource are set to a node, and each one type may be changed to other type, how can we assign them?

Thanks for your attendance.

Please fell free to contract with me if interested via zqxu@mail.xidian.edu.cn or Web.xidian.edu.cn/zqxu

Any question or comments?