JURNAL

Sains MIPA

Terakreditasi Dirjen DIKTI SK No.: 56/DIKTI/Kep/2005

Edisi Khusus Volume 14, No. 1, Tahun 2008

(Sebelumnya Terbit sebagai Jurnal Sains dan Teknologi)

J. Sains MIPA	Edisi Khusus Vol. 14	No. 1	Hlm. 1 - 81	Bandar Lampung Tahun 2008	ISSN 1978-1873

Jurnal Sains MIPA
ISSN 1978-1873

Terakreditasi Dirjen DIKTI SK No.: 26/DIKTI/Kep/2005 diperbarui dengan SK No.: 56/DIKTI/Kep/2005

Terbit 3 kali setahun pada bulan April, Agustus dan Desember berisi tulisan ilmiah hasil penelitian dasar dan telaahan (review) bidang matematika dan ilmu pengetahuan alam.

Alamat Penyunting dan Tata Usaha
Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Lampung
Jl. S. Brojonegoro No. 1 Bandar Lampung 35145 Telp. (0721) 701609 Pes. 706 Fax (0721) 704625;
E-mail: jsainsmipa@unila.ac.id, sutopohadi@unila.ac.id dan sutopo_hadi@yahoo.com.au
Rekening Bank BNI 1946 Cabang Unila, a.n. Sutopo Hadi, No. 0070705713.

J. Sains MIPA diterbitkan oleh Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Lampung. Terbit Pertama Kali Tahun 1995 dengan nama **Jurnal Penelitian Sains dan Teknologi**. Pada tahun 2003 berganti nama menjadi **Jurnal sains dan Teknologi (J. Sains Tek.)** dengan ISSN 0853-733X , dan pada tahun 2007 berganti nama kembali menjadi **J. Sains MIPA dengan** ISSN 1978-1873

Jurnal ini terbit di bawah tanggung jawab: Sugeng P. Harianto (Rektor), Pembina/Pengarah: Tirza Hanum (Pembantu Rektor I), John Hendri (Ketua Lembaga Penelitian), Sugeng P. Harianto (Dekan FMIPA)

KATA PENGANTAR

Alhamdulillah, walau agak terlambat, kami kembali hadir ditengah kita para peneliti secara umum dan peneliti MIPA pada khususnya. Keterlambatan ini karena banyaknya kendala teknis yang kami hadapi terutama menyeleksi banyaknya makalah yang masuk . Kami selalu berupaya dengan sungguh-sungguh agar Jurnal Sains MIPA ini menjadi salah satu jurnal nasional yang sejati, yang mempublikasikan makalah tidak hanya dari wilayah Sumatra, tapi dari seluruh Indonesia, seperti yang kami tampilkan saat ini.

Kami bahagia, karena berhasil menjumpai kembali para penulis dan peniliti secara umum dan peneliti bidang MIPA pada khususnya. Pada edisi Khusus Volume 14, No. 1 ini, kami muat 13 artikel ilmiah dari bidang Matematika. Artikel-artikel yang ditampilkan ini merupakan makalah pilihan dari hasil Seminar Nasional Sains dan Teknologi di Universitas Lampung tanggal 27-28 Agustus 2007. *Setting* dan tampilan setiap makalah dalam edisi kali inipun tidak seperti *setting* pada edisi regular, hal ini mengingat banyaknya makalah yang harus disetting. Kami berharap semoga makalah yang kami tampilkan pada edisi ini menarik bagi para pembaca.

Sebagai wahana komunikasi para peneliti, kami merasa masih banyak kekurangan dalam banyak hal. Untuk itu, kami dengan tangan terbuka selalu membuka kritik dan saran yang membangun demi kemajuan jurnal ini. Kami juga tetap berharap para peneliti untuk selalu mengirimkan hasil penelitiannya yang terbaru untuk diterbitkan pada jurnal ini, karena tanpa adanya artikel yang bermutu, maka kami tidak dapat hadir di tengah kita tepat waktu. Untuk itu, kami selalu berterima kasih atas kepercayaan para penulis dan peneliti yang mempercayakan jurnal ini sebagai media komunikasinya.

Bagi para pembaca yang ingin berlangganan, dapat melihat tata cara berlangganan pada bagian belakang pada setiap penerbitan. Akhir kata semoga pembaca dapat memanfaatkan tulisan ilmiah yang telah dimuat dalam edisi ini.

Bandar Lampung, Januari 2008

Dewan Penyunting

Jurnal Sains MIPA (ISSN 1978-1873)
Edisi Khusus, Volume 14, No. 1, Tahun 2008

Daftar Isi

J. Sains MIPA, Edisi Khusus Tahun 2008, Vol. 14, No. 1, Hal.: 1 - 6
ISSN 1978-1873

COMPUTATIONAL ASPECTS OF GREEDY ALGORITHM FOR SOLVING THE MULTI PERIOD DEGREE CONSTRAINED MINIMUM SPANNING TREE PROBLEM

Akmal Junaidi[1], Wamiliana[1], Dwi Sakethi[1] and Edy Tri Baskoro[2]

[1]Dept. of Mathematics, Faculty of Mathematics and Natural Sciences, Lampung University
[2]Dept of Mathematics, Bandung Institute of Technology

Received 28 August 2007, revised 10 December 2007, accepted 27 December 2007

ABSTRACT

Given one center already set, The Multi Period Degree Constrained Minimum Spanning Tree Problem (MPDCMST) is a problem of determining how many vertices (can be computers, cities, and so on) should be installed in a certain period in such a way so that the cost of installation is minimum. After all the periods done, all of the vertices must be in the network, and still the cost of installation must be the minimum. In addition, the network itself has a degree restriction in every vertex which limits the number of links that incident to. In this paper we will discuss the algorithm we have developed and give results on 600 random table data.

Keywords: *multi period, degree constrained, minimum spanning tree*

1. INTRODUCTION

Combinatorial (or discrete) optimization is one of the most active fields in the interface of operation research, computer science and applied mathematics. It has experienced a most impressive growth in recent years. This growth has been fuelled in a large part by the increasing importance of computer technology in business and industry and the demands from many application areas where discrete models play more and more important roles.

Network design as one of the areas of combinatorial optimization, plays an important role in many real-life applications. In this modern age where accurate models and efficient solution techniques are required, it provides the representation of problems at hand. Some examples of network design include: transportation networks for the movement of commodities; communication networks for the transmission of information; powerful multiprocessor systems for solving complex problems such as radar signal processing and many more.

Graph theoretic concepts[1-3] are important in studying problems arising in network design such as: the design of minimal cost network; the design of integrated circuits; the design of data communication networks capable of supporting large scale on-line applications; the design of powerful multiprocessors for solving complex problems (such as radar signal processing) in real time; determining optimal route in a given network; and many more.

The Degree Constrained Minimum Spanning Tree (DCMST) problem is concerned with finding a minimum-weight spanning tree whilst satisfying degree requirements on the vertices. The applications of the Degree Constrained Minimum Spanning Tree problems that may arise in real-life include: the design of telecommunication, transportation, and energy networks. It is also used as a subproblem in the design of networks for computer communication, transportation, sewage and plumbing. In Gavish[4], for example, used the DCMST as a subproblem in the design of a centralized computer network; and in Gavish[5] also provides several examples of optimization problems that are faced in the process of designing computer communication networks.

For solving the DCMST, the number of methods have been investigated which involve both exact and heuristics. Since this problem is NP-complete (as in Garey and Johnson[6]) many researchers interested in investigating heuristics methods. Some of heuristics investigated involved variations of Prim's and Kruskal's algorithms (as in Narula[7]), Genetic Algorithms in[8], Simulated Annealing in[9] . iterative refinement procedure was investigated[10, 11], Tabu Search[12-15] , and Modified Penalty[16].

The Multi Period Degree Constrained Minimum Spanning Tree (MPDCMST) is a problem derived from the Degree Constrained Minimum Spanning Tree Problem (DCMST). The difference of the two problems lies on the period in which restrict the network considered to be installed in some periods or stages. Usually, in real-life implementation, the installation must be done in some periods due to fund limitation. In DCMST, all the vertices (can represent computers, cities, and so on) can be installed in one period and there is no center vertex specified. This problem appears in some real-life problems such as installation of pipe for: water supply, liquid natural gas, electricity, telephone (cable) and so on.

In this paper we discuss some methods to solve the MPDCMST problem, and we organize this paper as follow: in section 1 we give introduction about the MPDCMST, how it is derived, in section 2 we give the formulation, in section 3 we discuss the algorithms developed, in section 4 we give the implementation results and finally in section 5 we give conclusion.

2. THE INTEGER PROGRAMMING FORMULATION FOR THE MPDCMST

The MPDCMST can be formulated as an integer programming formulation in [17] as follow:

$$Z_{ip} = Minimum\left\{ \sum_{i=2}^{m} \sum_{j=1}^{n} \sum_{t=1}^{T} c_{ijt} x_{ijt} \right\}$$

$$\sum_{i=1}^{n} \sum_{t \le p_j} x_{ijt} = 1 \quad \forall j \in N$$

$$\sum_{i=1}^{n} f_{ijt}^{k} - \sum_{i=2}^{n} f_{jit}^{k} = \begin{cases} +1 \ \text{if } t \ge p_k \text{ and } j = k \\ -1 \ \text{if } j = 1 \text{and } t \ge p_k \\ \quad 0 \quad \text{others} \end{cases} \qquad \forall j \in N \cup [1],\, k \in N,\, t \in L$$

$$\sum_{j=2}^{n} \sum_{\tau \le t} x_{ij\tau} \le b_i \quad \forall i \in N, t \in L$$

$$f_{ijt}^{k} \le \sum_{\tau \le t} x_{ij\tau} \qquad \forall i \in N \cup [1],\, j,k \in N,\, t \ge p_k$$

$$f_{ijt}^{k} \in \{0,1\} \qquad \forall i \in N \cup [1],\, j,k \in N,\, t \in L$$

$$x_{ijt} \in \{0,1\} \qquad \forall i \in N \cup [1],\, j \in N,\, t \in L$$

$$\sum_{i=1}^{n} \sum_{j=2}^{n} \sum_{t=1}^{L} X_{ijt} = (n-1)$$

3. THE DATA GENERATED AND THE ALGORITHMS

The data used in this research are generated uniformly and whose weight range from 1 to 1000 and all are integers. Besides, we test our methods using the bench marks problems downloaded from
http://www.iwr.uniheidelberg.de/iwr/comopt/soft/TSPLIB95/TSPLIB

a. *WDA 1 algorithm for the MPDCMST.*

begin
  $t \leftarrow 0$
  Initiation:: The numbers of vertices in the network, center vertex, the number of periods.
    Sorts edges in increasing order.
  while (Stopping criteria not satisfied)
    do
   $t \leftarrow t+1$
   Find the smallest edge which adjacent to the vertices that have to be installed in period t.
    if (degree constrained satisfies)
    Connects this edge to the network. .


```
            else
            Continue searching in this period
            if ( Possible to add other vertices)
            Choose the smallest edge to be installed in the network.
            else
            t ← t + 1
              endif
   endif
  end
end
```

a. *WDA 2 Algorithm for MPDCMST*

The difference of this algorithm with WDA 1 lies on the sorting edges. In this algorithm no needs to sort the edges, but we perform preprocessing steps as follow:

Prepocessing

Step 1. Chose a vertex to be installed (except vertex 1 as center vertex) randomly at the first period.

Step 2. Connect that vertex to vertex 1.

Step 2. Repeat

Choose (randomly) smallest edge that must be installed at period 1.

If

Every vertex in the subgraph formed has degree maximum *b*-1 (*b* is the degree restriction), and not forms cycle, then install that edge.

Else,

Discard that edge

Until

DCST formed on the first period.

Pseudocode for WDA 2 :

```
begin
      t ← 0
      Inition:: The number of vertices in the network, center vertex, the number of period, initial solution, max vertex can
        be installed on period t, the number of vertices must be installed on period t ( t =2,3,..)
 while (Stopping criteria is not satisfied)
            do
        t ← t + 1
        Choose (randomly) vertex from the vertices that must be installed on period t.
            if (Degree restriction are satisfied)
            Installed that edge in the network (possible to forms forest)
            Continue searching on this period

            if ( Possible to add other vertices)
            Choose the sammlest edge to be installed in the network.
            else
            t ← t + 1
                 endif
          endif
       end
end
```

c. *WDA 3 algorithm for MPDCMST*

The idea of this algorithm is similar with WDA2 except on vertex choosing where on this period we choose the smallest vertices and without considering the incident of those vertices to the center vertex; and we do this process iteratively. The preprocessing of this algorithm is given as follow:

Prepocessing WDA 3

Step 1. Repeat

Choose (randomly) the smallest edge incident to the vertices that must be installed on period 1. (Put vertex 1 as part one of the vertices must be installed).

If

Every vertex in the sub graph formed has degree maximum *b*-1 (*b* is the degree restriction), and not forms cycle, then install that edge.

Else,

Discard that edge

Until

DCST formed on the first period

For the next steps are the same as WDA 2.

4. RESULTS AND IMPLEMENTATION

We implement our methods using C language programming running PC based Linux operating system. We give our results on figures and table below:

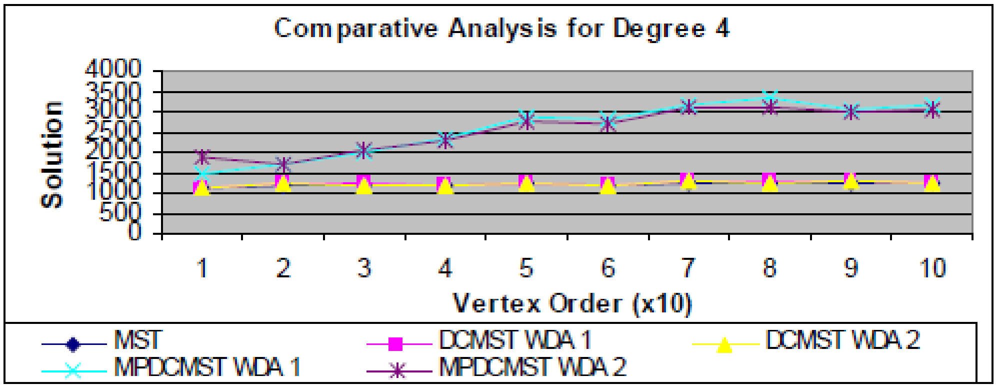

Figure 1. Comparative for degree 4, the number of period 3

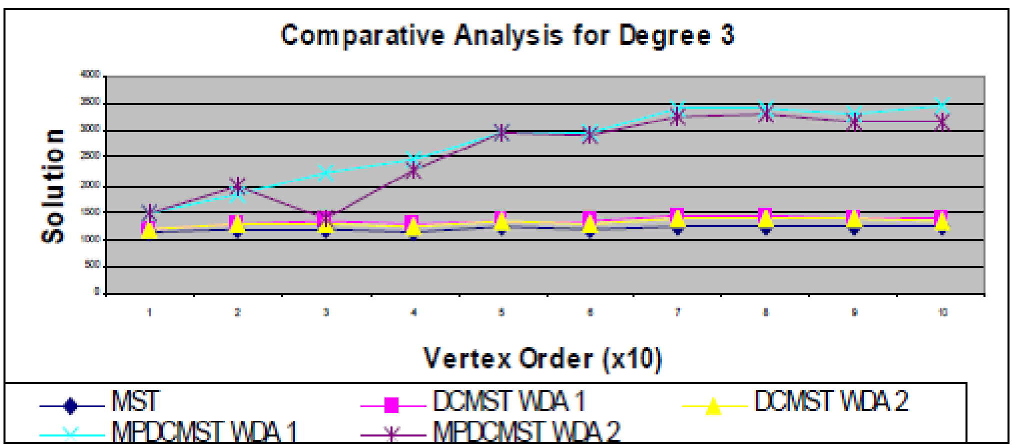

Figure 2. Comparative for degree 3, the number of period 3

Table 1. Implementation on TSPLIB Problem

File name	MST	DMST				Jml	MTDMST					
		Degree = 3		Vertek		Vertek	Degree = 3			Degree = 4		
	Optimum	Optimum	H-LB/LB	Optimum	H-LB/LB	Hr diinstal	Optimum	H-LB/LB	Time	Optimum	H-LB/LB	Time
Rat575	6248	6252	0.06%	6248	0.00%	47	6436	2.94%	865	6420	2.75%	872
						141	7111	13.74 %	953	7034	12.58 %	979
Att532	43475	43490	0.03%	43475	0.00%	44	4918	13.09	880	48922	12.53	875
						132	56682	30.33 %	878	55980	28.76 %	885
Pr264	41142	41143	0.00%	41142	0.00%	22	4541	10.38	45	45335	10.19	45
						66	46920	14.04 %	47	46920	14.04 %	46

4. CONCLUSION

Based on the computational results, running on 600 random table problem, our results are feasible, compared to the previous data[17] where 70% of the data generated are infeasible. However, since this problem still new and so far only two paper already publish considering this problem[17, 18] there are still a lot of possibilities to investigate and develop other methods to solve this problem to get better solution.

REFERENCES

1. Caccetta, L. 1989, 'Graph theory in network design and analysis', in Kulli, V.R. (ed.), *Recent Studies in Graph Theory*, Vishwa International Publications, India, pp26-63.
2. Caccetta, L. and Vijayan, K. 1987, ' Applications of Graph theory', *Ars Combinatoria*, 23 (B), pp 21-77.
3. Ahuja, R.K., T.L Magnanti and J.B. Orlin ,1993. *Network Flow: Theory, Algorithms and Applications*, Chapter 13, Prentice Hall, Englewood Cliff, New Jersey, USA.
4. Gavish, B ,1985 ' Augmented Lagrangean based algorithms for centralized network design' , *IEE Transaction of Communication*, .33, pp.1247-1257
5. Gavish, B,1992. 'Topological Design of Centralized Computer Networks the Overal Design Problem ', *European Journal of Operations Research*, 58 , pp.149-172.
6. Garey, M.R. , and Johnson, D.S.1979. *Computers and Intractibility, A Guide to the Theory of NP-Completeness*, Freemann, San Francisco.
7. Narula,S. C., and Ho, C.A. 1980, Degree-Constrained Minimum Spanning Tree, *Computer and Operation Research* , Vol. 7,pp. 239-249.
8. Zhou, G., and Mitsuo Gen.1997. ' A Note on Genetics Algorithms for Degree- Constrained Spanning Tree Problems', *Network*, Vol. 30, pp.91 - 95.
9. Krishnamoorthy, M., A.T. Ernst and Yazid M Sharaila ,2001, 'Comparison of Algorithms for the Degree Constrained Minimum Spanning Tree', *Journal of Heuristics*, Vol. 7, no. 6, pp. 587-611.
10. Boldon, B., N. Deo and Nishit Kumar ,1996. ' Minimum Weight degree-constrained spanning tree problem: Heuristics and Implementation on an SIMD parallel machine', *Parallel Computing* vol. 22, pp.369 –382.
11. Deo N. and Nishit Kumar,1997, 'Computation of Constrained Spanning Trees: A Unified Approach', *Network Optimization* (Lecture Notes in Economics and Mathematical Systems, Editor : Panos M. Pardalos, et al , Springer-Verlag, Berlin, Germany, pp. 194 – 220.

12. Caccetta, L., and Wamiliana, Heuristics Algorithms for the Degree Constraine Minimum Spanning Tree Problems, in Proceeding of the International Congress on Modelling and Simulation (MODSIM 2001), Canberra, Editors: F. Ghassemi et.al, pp. 2161-2166,2001.

13. Caccetta L. and Wamiliana,,2003. "A First Level Tabu Search Method for the Degree Constrained Minimum Spanning Tree", *Journal of Quantitative Methods*, 1 No.1, pp. 20-32.

14. Wamiliana,2004, Solving the Degree Constrained Minimum Spanning Tree Using Tabu and Penalty Method, *Jurnal Teknik Industri*, 6, pp.1-9.

15. Wamiliana and L. Caccetta, 2004. "Tabu Search Based Heuristics for the Degree Constrained Minimum Spanning Tree Problem", Proceeding of South East Asia Mathematical Society Conference, pp. 133-140.

16. Wamiliana ,2002. The Modified Penalty Methods for The Degree Constrained Minimum Spanning Tree Problem, Jurnal Sains dan Teknologi, Vol. 8, pp.1-12.

17. Kawatra R. (2002). "A multiperiode degree constrained minimum spanning tree problem", *European Journal of Operational Research*, 143, pp 53-63.

18. Wamiliana, Dwi Sakethi, Akmal J and Edy Tri Baskoro, 2005.' The Design of Greedy Algorithm for Solving The Degree Constrained Minimum Spanning Tree Problem' *Jurnal Sains dan Teknologi*, Vol. 11 No.2 , pp. 93-96.