LIB Laboratoire Informatique de Bourgogne

UNIVERSITÉ DE BOURGOGNE

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

école doctorale **sciences pour l'ingénieur et microtechniques** SPIM

Titre de la thèse :

A study of Optimized Spanning Trees and their use in Computer Networks

Host Laboratory :

LIB Laboratory, University of Burgundy, Dijon, Frane

Speciality :

Computer Science

Keywords :
Spanning tree; Graph ; Optimization; Algorithm; Networks

Job description

Every connected graph containing cycles possesses many spanning trees. Defining and using many spanning trees in a graph or within a network can be of practical interest, for instance in IoT (Internet of Things) mesh, ad-hoc and data center networks [2, 13, 11,17], through improved reliability and Quality of Service (QoS) in these networks in particular if the spanning trees' disjunction is optimized. The spanning trees T1, T2, … , Tk of a graph G are completely independent spanning trees (CISTs for short) if for every nodes x and y, the paths between x and y in the tree Ti are pairwise vertex disjoint except on their end-vertices.
Since its introduction by Hasunuma in 2001 [8], the problem attracted many research works. The problem of deciding if a graph has two CISTs is NP-complete [9]. Araki [1] provided a Dirac type condition for a graph to have k CISTs. Various authors proved the existence of two or three CISTs in some hypercube variants [14, 4, 16, 3]. On other classes of graphs there are partial results for planar graphs [9], product graphs [10, 6], partial k-trees [12], Cayley graphs [15]. As most of the graphs do not even have two CISTs, Darties et al. [7] introduced a relaxation of the problem by defining (i,j)-ISTs by allowing the spanning trees to share at most i internal nodes and at most j internal edges in total.

The objective of this thesis is to remove several research barriers and to propose innovative solutions. Thus, we specify as research axes the study of optimized CISTs and (i,j)-ISTs on both the theoretical (existence/non-existence proofs), algorithmical (heuristics, parameterized complexity), and practical (usefulness of these structures to address problems in emerging networks such as the Internet of Things as well as 5G and 6G networks) aspects. In particular, possible starting points can be to:

- Find many optimized (i,j)-IST (with small i and/or j) in new graph classes, for instance circulant or Kneser graphs or to optimize the maximum diameter (or mean distance) of the built spanning trees;

- Propose new heuristic methods for finding CISTs or (i,j)-IST in an arbitrary graph and test them on real graphs as well as networks;

- Investigate the use of CISTs and (i,j)-ISTs in the field of networking wile considering current and emerging network environments (Internet of Things (IoT), new generations of 5G/6G mobile networks, Cloud Computing/Networking, VANETs, etc.).

Bibliography

[1] T. Araki. Dirac's condition for completely independent spanning trees. Journal of Graph Theory, 77(3):171–179, 2014.

[2] H. Bargaoui, N. Mbarek, O. Togni, and M. Frikha, Hybrid QoS based routing protocol for inter and intra wireless mesh infrastructure communications, J. Wireless Networks, 22(7): 2111-2130, 2016.

[3] G. Chen, B. Cheng, and D. Wang. Constructing completely independent spanning trees in data center network based on augmented cube. IEEE Transactions on Parallel and Distributed Systems, 32(3):665–673, 2020.

[4] B. Cheng, D. Wang, and J. Fan. Constructing completely independent spanning trees in crossed cubes. Discrete Applied Math., 219:100–109, 2017.

[5] B. Cheng, D. Wang, and J. Fan. Independent spanning trees in networks: A survey. ACM Computing Surveys 55(14s), 2023.

[6] B. Darties, N. Gastineau, and O. Togni. Completely independent spanning trees in some regular graphs. Discrete Applied Math., 217:163–174, 2017.

[7] B. Darties, N. Gastineau, O. Togni, Almost disjoint spanning trees: relaxing the conditions for completely independent spanning trees, Discrete Applied Math., Volume 236, 19 February 2018, Pages 124-136.

[8] T. Hasunuma. Completely independent spanning trees in the underlying graph of a line digraph. Discrete math., 234(1-3):149–157, 2001.

[9] T. Hasunuma. Completely independent spanning trees in maximal planar graphs. In 28th Int. Workshop, WG 2002 Czech Republic, 2002 Revised Papers 28, pages 235–245. Springer, 2002.

[10] T. Hasunuma and C. Morisaka. Completely independent spanning trees in torus networks. Networks, 60(1):59–69, 2012.

[11] X.-Y. Li, W. Lin, X. Liu, C.-K. Lin, K.-J. Pai, and J.-M. Chang. Completely independent spanning trees on bccc data center networks with an application to fault-tolerant routing. IEEE Transactions on Parallel and Distributed Systems, 33(8):1939–1952, 2021.

[12] M. Matsushita, Y. Otachi, and T. Araki. Completely independent spanning trees in (partial) k-trees. Discussiones Mathematicae: Graph Theory, 35(3), 2015.

[13] A. Moinet, B. Darties, N. Gastineau, J.-L. Baril, and O. Togni. Completely independent spanning trees for enhancing the robustness in ad-hoc networks. In 2017 IEEE WiMob, Conference, pages 63–70, 2017.

[14] K.-J. Pai and J.-M. Chang. Constructing two completely independent spanning trees in hypercube-variant networks. Theoretical Computer Science, 652:28–37, 2016.

[15] K.-J. Pai, R.-S. Chang, and J.-M. Chang. Constructing dual-cists of pancake graphs and performance assessment of protection routings on some cayley networks. The Journal of Supercomputing, 77(1):990–1014, 2021.

[16] K.-J. Pai, R.-S. Chang, R.-Y. Wu, and J.-M. Chang. Three completely independent spanning trees of crossed cubes with application to secure-protection routing. Information Sciences, 541:516–530, 2020.

[17] B. Yao *et al*., "Applying Graph theory to the Internet of Things," *2013 IEEE 10th International Conference on High Performance Computing and Communications & 2013 IEEE International Conference on Embedded and Ubiquitous Computing*, Zhangjiajie, China, 2013, pp. 2354-2361, doi: 10.1109/HPCC.and.EUC.2013.339.

Applicant profile

We are looking for a good candidate (Master's degree, engineer or equivalent in computer science or mathematics) with skills in the fields of graphs and networks:

- Graph theory, Technologies used in networks: TCP / IP architecture, etc.

- Network simulation: NS3/NS2/OMNET ++
- Object-oriented programming: C ++ / Java.

Financing institution : MESRI Etablissement

Application deadline : 1st June 2024
Start of contract : 1st Octobre 2024
Monthly gross salary: 2100€

Thesis Supervisor

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Thesis Co-Supervisors

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Applicants are invited to submit their application to the PhD supervisor and co-supervisors listed above. Application must contain the following documents:

- ✓ A detailed CV
- ✓ Cover letter
- ✓ Transcripts and results in Bachelor, Master, or equivalent degrees (while indicating your ranking and the number of students)
- ✓ At least 1 reference letter