University of Seville / Department of Applied Mathematics

Seville, August 28, 2026

Doctoral dissertation review

Titled:

Management of a Communication Network: A Cooperative Game Approach

This review of the doctoral dissertation, authored by Mr. Rajiansyah, M.Sc. Eng., was commissioned by the Chairman of the Disciplinary Council for Technical Information Technology and Telecommunications, Prof. Dr. Hab. Eng. Wojciech Bożejko. The supervisor of this dissertation is Dr. hab. inż. David M Ramsey, Prof. Uczelni, and the auxiliary supervisor is dr. inż. Dariusz Gąsior. The doctoral dissertation is written in English. The dissertation submitted for review was carried out as part of the implementation doctorate program.

1. The research problem and its significance

This dissertation addresses the strategic, operational, and economic management of multi-provider communication networks through the combined analytical framework of coalitional game theory and multicommodity flow optimization. The central problem focuses on how independent telecommunication operators—each controlling distinct structural segments of a shared infrastructure—can collaboratively route data traffic to maximize aggregate system earnings while establishing a fair and stable profit-sharing distribution.

This is a strictly scientific problem, standing at the intersection of graph theory, operations research, and cooperative game theory. By modeling communication infrastructures as weighted connected graphs with operational capacity limits and unit transmission costs, the author deals with coalitional characteristic functions that evaluate the joint economic earnings of candidate provider alliances. This enables an analysis of foundational solution concepts, such as the Shapley value (Shapley, 1953), alongside network-restricted allocations including the Myerson value (Myerson, 1977) and the S-value (Hellman & Peretz, 2018).

From an applied perspective, executed within the framework of an Implementation Doctorate Program, this research possesses direct practical relevance for modern telecommunication consortia. As escalating network expansion costs drive multi-domain infrastructure sharing, the candidate uses the presented mathematical models to propose conceptual algorithmic mechanisms intended to guarantee individual rationality, sustain coalition stability, and prevent strategic deviation among competing service providers.

2. Author's contribution

Mr. Rajiansyah presents several scientific and technical contributions to the fields of inter-domain routing and economic revenue allocation. Rather than restricting the analysis to a static baseline setup, the author builds a logical hierarchy of models, systematically moving from unconstrained linear cost networks in Chapter 4 to complex multicommodity flow optimization under explicit capacity bounds in Chapter 5. This theoretical progression allows the framework to capture more realistic operational scenarios in modern data networks.

In modeling topological dependencies, the candidate incorporates graph-restricted profit allocation mechanisms, specifically applying the Myerson value (Myerson, 1977) and the S-value (Hellman & Peretz, 2018) to capture the physical reality that providers controlling adjacent network domains form cooperative alliances more naturally than geographically disconnected operators. The conceptual structure of the presented communication network aligns directly with established methodologies for multi-operator infrastructure sharing as colored/labeled graph network games. To ensure full formal rigor and complete transparency regarding the originality of the candidate's results, it is essential to provide a clear demarcation between the baseline model architecture—specifically the colored/labeled network allocation framework (Algaba et al. 2019a; 2019b)—and the candidate's specific operational extensions (namely, the introduction of explicit link capacity constraints and traffic flow bounds) when introducing the communication network framework. Moreover, incorporating the foundational reference: *"Labeled Network Allocation Problems: An Application to Transport Systems" (Algaba et al. 2019b)* into the framework at the very outset of the model formulation, both in this manuscript and in future work, contextualizes the theoretical lineage of the model while highlighting the candidate's novel contributions. Proper citation substantially enhances the value of the work.

Furthermore, the dissertation introduces measures of proportional and uniform economic centrality to evaluate edge (link) importance based on actual traffic flow, unit costs, and generated routing revenues. While these metrics share a strong conceptual foundation with the coloured proportional solution and the coloured egalitarian solution introduced in Algaba et al. (2019a), making this theoretical connection explicit and including a comparative analysis —both in the current manuscript and in future works derived from this research—would further enrich the framework and discussion. The candidate conducts a comparative evaluation between these economic centrality metrics and game-theoretic solutions, demonstrating that while economic centrality provides lower computational complexity suitable for large networks, it assesses link value strictly under the grand coalition and can yield allocations that lie outside the Core (Gillies, 1959). Finally, for capacity-constrained settings, the candidate proposes an auction-based valuation mechanism utilizing iterated second-price auctions (Vickrey, 1961) to calculate coalition values, bridging competitive path bidding with coalitional profit allocation.

3. Correctness

The mathematical derivations, optimization formulations, and theoretical arguments presented across the manuscript are executed with technical consistency within their declared boundary conditions. The candidate handles linear programming duality, multicommodity flow algorithms, and cooperative game theory. In Chapter 4, the author proves the superadditivity of the characteristic function for unconstrained linear cost networks and establishes that Shapley value (Shapley, 1953) allocations guarantee Core (Gillies, 1959) stability. In Chapter 5, the subgame formulation under capacity constraints and the iterated second-price auction mechanism provide a mathematical framework for evaluating constrained routing economics.

The candidate acknowledges the current theoretical and computational limitations of the framework. The manuscript notes that while superadditivity holds for unconstrained linear models, proving whether general capacity-constrained flow games are balanced or superadditive remains an open theoretical challenge. Similarly, the author clearly distinguishes between the Chapter 4 model, which has been fully automated, and the Chapter 5 capacity-constrained model, where algorithmic automation for subgame coalition valuations remains an open implementation goal.

From a theoretical perspective, an important methodological observation arises regarding the candidate's framing of centrality metrics. While the author contrasts operational economic centrality against standard structural graph metrics (such as degree or betweenness centrality, Freeman, 1978), the manuscript does not fully engage with established game-theoretic centrality solution concepts in the network literature. Specifically, the Position value (Meessen, 1988; Borm et al., 1992), which stands as the game-theoretic solution concept explicitly designed to evaluate the importance of nodes in communication graphs depending on the degree of a node, is not integrated into the contextual framework. Other structural game-theoretic measures in the literature—such as the Shapley value for network centrality (Shapley, 1953; Husslage et al., 2015; Hamers et al., 2019) are not discussed either.

4. Candidate knowledge

Chapters 1 through 3 provide evidence of the candidate's academic foundation and theoretical understanding of Technical Information Technology and Telecommunications. Chapter 1 frames the operational and market challenges of multi-operator infrastructure sharing in modern telecommunication architectures, reflecting the practical orientation of the Implementation Doctorate context. Chapter 2 offers an exposition of the mathematical toolkit—spanning operations research, graph theory, and coalitional game theory— while Chapter 3 provides a structured review of inter-domain routing and resource allocation literature, where a discussion of the foundational coloured/labeled network allocation framework (Algaba et al. 2019a; 2019b) would provide essential theoretical context to clarify the conceptual lineage of the extended model presented in this work.

The narrative is supported by an extensive bibliography. However, for future publications, journal submissions, and revision from this research, the theoretical contextualization would be further strengthened by ensuring that primary foundational sources are cited directly where key concepts are introduced, rather than relying on secondary literature or indirect citations. Specifically:

- The reference to *"Labeled Network Allocation Problems: An Application to Transport Systems"* (Algaba et al. 2019b), which extends the colored network setting introduced in Algaba et al. (2019a), aligns directly with the modeling approach of this manuscript. Therefore, incorporating this foundational work would be fundamental, when presenting the model of communication networks of this work, to complete the theoretical mapping of the network modeling techniques employed throughout this thesis and future works.

- The introduction of graph-restricted communication games and the Myerson value should be anchored directly to Myerson (1977), alongside explicitly linking the colored graph network framework to Algaba et al. (2019a).

- The review of classical cooperative concepts should cite foundational primary references, including Gillies (1959) for the Core, as well as Bondareva (1963) and Shapley (1967) for game balancedness.

- The edge and node centrality framework should explicitly incorporate the literature on the Position value (Meessen, 1988; Borm et al., 1992) and established subsequent game-theoretic centrality metrics to provide a comprehensive bridge between engineering-oriented routing protocols and structural game-theoretic network analysis.

To ensure that these essential theoretical connections, primary references, and comparative clarifications are formally integrated into the permanent record of the dissertation, the candidate should provide a formal Errata Sheet prior to the public defense and incorporate all these corrections into the final archived manuscript.

Overall, the candidate demonstrates an appropriate command of the theoretical principles and practical application methods required in the discipline of Technical Information Technology and Telecommunications.

5. Other notes

The dissertation is written in precise, grammatically sound academic English. The narrative progresses clearly from mathematical definitions to optimization models.

Summary

Taking into account the opinions presented in the previous points and the requirements defined by Article 187 of the Act of 20 July 2018 - Law on Higher Education and Science (as amended) my assessment of the dissertation in terms of three basic criteria is as follows:

A. Does the dissertation contain an original solution to a scientific problem?

[X] Definitely YES

[ ] Probably YES

[ ] It's hard to say

[ ] I don't think so

[ ] Definitely NOT

B. After reading the dissertation, do you agree that the candidate has general theoretical knowledge in the discipline of Technical Information Technology and Telecommunications?

[X] Definitely YES

[ ] Rather YES

[ ] It's hard to say

[ ] I don't think so

[ ] Definitely NOT

C. Does the candidate have the ability to conduct research independently?

[X] Definitely YES

[ ] Rather YES

[ ] It's hard to say

[ ] I don't think so

[ ] Definitely NOT

Signature: Prof. Dr. Encarnación Algaba/ Reviewer