Game-Theoretic Multi-Agent Large Language Models for Auction Simulation and Trading

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Abstract/Project Goal

The primary objective of this project is to leverage the simulation platform described in the referenced paper to create a digital twin using a multi-agent model, specifically for radio spectrum auctions in the telecommunications industry. This approach aims to develop a regulatory sandbox to enhance the decision-making process regarding the formulation of rules and the design of optimal spectrum auctions. The spectrum auction was modeled as a game in which five telecommunications operators competed to acquire a portion of the 120 MHz spectrum to offer mobile services. Three rounds were conducted, and in each round, insights were identified to refine and improve the auction rules.

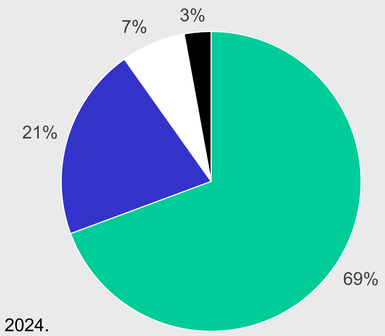
Introduction

Game theory, a branch of mathematics, studies **strategic interactions between rational agents** and finds applications in economics, social sciences, computer science, and biology. **Large language models can replicate real-life scenarios of game theory,** circumventing the high costs associated with human subject simulations. The reference paper, “ALYMPICS: Language Agents Meet Game Theory” (Shaoguang et al., 2023), introduces a simulation sandbox platform that enables the recreation of these scenarios.

The Mexican mobile services market has faced complex issues in economic competition, dominated by a telecom operator with around 70% market share. The objective here is to optimize the rules of spectrum auctions to foster greater competition in the mobile telecommunications market. Each operator's prompt reflects their behavior, budget, and decision-making processes based on their "personality traits" and other parameters.

The hypothesis is that the platform described in the reference article can be applied to the spectrum auction scenario to **create a digital twin that simulates real auction conditions**. This digital twin would provide valuable feedback to modify and enhance the auction rules.

Market share of mobile telecommunications operators



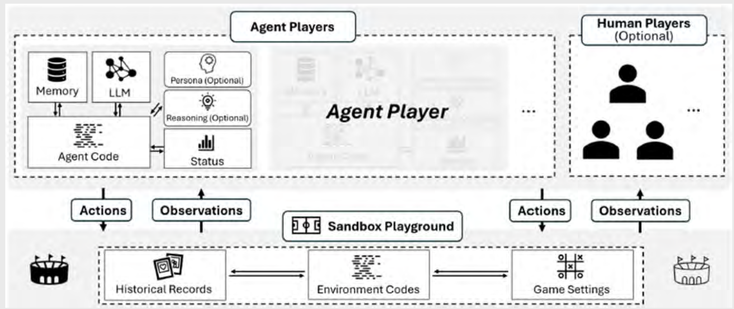
Source: Statista. 2024.

Methods

The experiments conducted by the reference paper were made with ChatGPT 4o, but the experiments conducted in this research have been conducted with **LLM ChatGPT 3.5 turbo** due to budget restrictions.

The simulation of a **telecom spectrum auction game** initializes players with predefined profiles, which contain a detailed description prompts of their behaviors, investment strategies and budget. The class includes methods to run auction rounds, determine winners, and update the game state. It uses a language model to recreate and interpret players' bids and generate the results of each round.

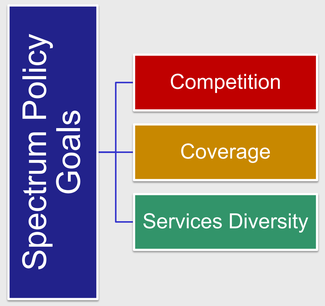
The **goal of the game** is to assign spectrum blocks to various telecommunications operators through an auction process, in which players make offers and win spectrum blocks based on their offers and needs.



Source: Shaoguang et al. 2023.

Results

Scenario	Playground Description	Number of winners	Operator	Spectrum acquired	Output Playground
1	3 Rounds 5 Telecomm operators **Without ex ante rules**	2	America Movil (TELCEL)	100	**High spectrum concentration in the market**
			Virgin Mobile	20	
2	3 Rounds 5 Telecomm operators **Price cap rule for PEA**	2	America Movil	50	**Less concentration but the winners are two operators with infrastructure. Small MVNOs are out.**
			ATT	60	
3	3 Rounds 5 Telecomm operators **Price cap rule for PEA** **Rights of way for MVNOs provided by government**	4	America Movil	50	**Close to optimal scenario with 4 winners, three of them are MVNOs**
			Virgin Mobile	20	
			Freedom Pop	40	
			BAIT	10	



Spectrum Policy as Competition Market Tool		Decision Making Process	
Scenarios	**Insights**	Rules for players	Rules for playground
1	High risk related with economic competition in market	Promote to establish a spectrum cap for PEA (TELCEL)	
2	It works the last action (price cap) but we could improve MVNOs		Establish a special rights of way subsidy for MVNOs
3	Close to the optimal scenario	Rules closed	Rules closed

Conclusions

➢**Multi-agent models can be used to simulate real life scenarios like spectrum auctions successfully.**

➢ **Prompts affect behavior of each agent (telecom operator) in the bidding process.**

➢**We can change parameters to modify sandbox playground as rules of the spectrum auction and simulate policies.**

➢**Multi-agent models could be useful to develop regulatory sandboxes and public policy design including spectrum policy.**

Future Work

There is a targeted agenda for utilizing multi-agent models to optimize simulations of spectrum auctions. This involves leveraging other LLM models, refining prompts, and executing numerous scenarios. Additionally, **these models can be applied to enhance trading operations** by incorporating multiple agents as trading and advisory entities **to improve stock purchase decisions** for Nasdaq companies and others. Reviewing the referenced author's work on K-level reasoning is essential for applying it to stock predictions.

References

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