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Abstract

Coalition formation is an important issue in multi-agent systems. Recent work in the area has focused on reducing the complexity of forming coalitions, i.e., each agent deliberately searches for potential coalition members before negotiating with them. We propose a framework for coalition formation of agents in a dynamic supply chain environment. The framework is composed of a negotiation protocol and a decision mechanism. The negotiation protocol allows thorough communication among agents across sectors (buyers, sellers, logistic providers). With the decision mechanism, agents take two steps to form coalitions: i) agents in each sector form loosely-coupled coalitions in order to decrease the complexity of the negotiation, and ii) agents form coalitions across sectors in order to deliver goods to end customers. We provide an example of how they can help agents form coalitions successfully.

Keywords: coalition formation, dynamic supply chain, negotiation

1. Introduction

The current business environment is characterized by large complex supply chains that are often global in reach and that are highly adaptive, being frequently reconfigured to respond to dynamic business contexts. It is widely recognized that collaboration across the supply chain is a key prerequisite for supply chain efficiency. The effective deployment of information technology and systems, especially the internet and the web, has made new modes of complex, dynamic yet effective collaboration possible across supply chains. Collaboration in supply chains can take various forms. Suppliers and buyers might collaborate to increase buying/selling power, to reduce logistics costs or to aggregate capacity. The problem of determining an optimal set of collaborative arrangements/agreements for a given firm can be complex. This research seeks to develop automated (or semi-automated) negotiation protocols as a basis for building decision support tools for dealing with this complexity.

The coalition formation problem (Kahan et al. 1984, von Neumann et al. 1953) considers techniques and criteria that might be used by a collection of (rational) agents to decide how they might group together to improve individual or social utility. Coalitions are ubiquitous in real-life settings. The theoretical underpinnings of approaches to coalition formation lie in the literature on multi-player games in game theory (von Neumann et al. 1953). Players negotiate among themselves about payoffs to decide which coalition to join. The simplest example of coalition formation (Kahan et al. 1984) is a small market game, where a seller has a good on sale and two buyers are bidding for it. The seller has a value for the good in mind and is unwilling to accept offers below this price (this is often referred to as the seller's *reserve price*.) Each buyer also has a private evaluation of the worth of the good (this is called the buyer's *reserve price*.) Buyers compete with each other by offering a price for the good to the seller. When a buyer and a seller reach an agreement, they may be viewed to have formed a coalition. The value of a coalition is the difference between the buyers' and the sellers' reserve prices. The negotiation between the seller and a buyer on price can be viewed as negotiation to divide the value of the coalition. The difference between the final price and the individual reserve prices is the payoff to the seller and buyer respectively. Coalitions in supply chains are typically far more complex than this, but the example highlights several of the key concepts involved. Within a supply chain, a coalition can be a group of buyers agreeing to buy a bulk order of a certain good in order to share some discounts, or a group of logistic providers (LPs) agreeing to coordinate their activities in order to optimally utilize their resources.

Agents in dynamic environments such as supply chains, must operate under heterogeneous constraints. Traditional accounts of coalition formation assume that the value of every possible coalition is known to all agents. In our setting this is not the case — a more complex negotiation protocol is used to determine which coalition an agent might join. We believe that the two key components of successful coalition formation of self-interested agents are, one, quickly negotiating with other agents and, two, selecting the best possible coalition. Each agent, bounded by its own constraints, may negotiate with others to form a coalition, which is likely to yield maximum benefit. Such a coalition, however, may not be formed due to the constraints. So the agent has to look for the next best possible coalition by consulting with its internal utility mechanism. Negotiation and decision must be done in a timely fashion. Agents may not need to compute for every exact utility it would achieve before negotiating. They can begin negotiation as quickly as possible, starting from the candidate who seems to offer the best deal onward. There are works in coalition formation that discuss the formation of buyers, sellers and LPs separately. This work provides a basic framework that allows thorough collaboration among agents in a supply chain. It includes two important components: a negotiation protocol and a decision mechanism. The negotiation protocol allows agents to exchange necessary information before deciding which coalition to join. A coalition can be as complex as a coalition of buyers, sellers and LPs. We restrict attention to traditional supply chain activities for the sake of simplicity. Our focus is primarily on material flows, but note that many of the concepts developed in this work could apply equally well to these other forms of collaboration.

2. Coalitions in Dynamic Supply Chains

There are many different motivating factors that make firms collaborate. In other words, there are multiple distinct drivers for coalition formation. Let us consider some of these below. In the following, we shall treat an agreement to buy/sell as a form of collaboration, in addition to the usual connotation of the term. The simplest form of a supply chain coalition is one where a buyer forms a coalition with a seller and an LP to satisfy one of the external activities in a plan (e.g. to supply and deliver a manufacturing input to a production process). Buyers sometimes form coalitions with other buyers for the purpose of buy-side aggregation, i.e., the aggregation of buying power. A simple example of such a coalition involves several small buyers with similar needs coming together to obtain greater bargaining power with larger suppliers.

Sellers sometimes form coalitions with other sellers to aggregate selling power. In some settings, there are legal impediments to certain forms of such coalitions (specifically cartels) in the form of anti-trust laws. However, such coalitions are common for small sellers, such as in agricultural cooperatives (e.g. for micro-producers of dairy products). Sellers sometimes form coalitions to aggregate/augment capabilities. Consider a scenario where seller s_1 is able to manufacture component c_1 while seller s_2 is able to manufacture component c_2. There is no market demand for c_1 and c_2 in isolation, but there is demand for product p_1 obtained by the assembly of c_1 and c_2. In this instance, there are obvious motivations for s_1 and s_2 to form a coalition. Both buyers and sellers may sometimes form coalitions to minimize logistics costs. Thus, a set of small buyers in close geographic proximity might form a coalition to aggregate their (relatively small) orders into a single load that might be shipped on one truck or in one container.

LPs may want to form coalitions to aggregate their service capacities. Two small trucking companies, l_1 and l_2, might not have sufficient transportation capacity to bid for a larger trucking contract. However, when their trucking capacities are aggregated via a coalition, the resulting entity is viable for bidding for the contract. Sometimes sellers and LPs might form coalitions to aggregate production and logistics capabilities in order to provide a higher-level of service to buyers. In such situations, a seller might conclude a contract with a buyer (or several buyers) to both produce a good and deliver it to the buyer's facilities. In such situations, the seller might form a coalition with one or more LPs to be able to service such contracts. We note that we have only listed the basic drivers. Most real-life supply chain coalitions tend to have more than one motivating factor driving their formation. Thus a coalition consisting of several sellers and several LPs might be driven by the need to aggregate selling power (for the sellers), the need to aggregate production capabilities (again for the sellers) and the need to offer comprehensive production and delivery contracts (thus bringing in one or more LPs into the coalition). We also note agents/actors (i.e., buyers, sellers or LPs) could participate in more than one coalition at any given point in time. Thus a seller might participate in a coalition with other sellers to aggregate selling power, while simultaneously participating in a coalition with a different set of sellers in order to aggregate manufacturing capabilities.

Both quantitative and qualitative factors play a role in coalition formation decisions. Price, delivery cost and lead time are examples of the former while quality, satisfaction and trust are examples of the latter. In the current work, we focus on qualitative factors - while acknowledging that other criteria might be relevant (though possibly less important). Most decisions typically involve trade-offs between several attributes. One may be willing to pay more for a shorter lead time (or higher quality or higher trust/reliability) and vice versa. One may, in some settings, be willing to accept longer lead times for the purpose of getting higher quality. Several other instances of such trade-off are common, but we do not list them all here.

Although negotiation can be either bilateral or multilateral, we can in most instances reduce negotiation to the bilateral case without loss of generality. The simplest scenario is where single agents negotiate, e.g., a buyer with a seller and a buyer with an LP. A buyer can bilaterally negotiate with multiple sellers/LPs at the same time in order to find the best pair of a seller and an LP. The information exchanged is kept private to each agent. A more complex scenario is where multiple agents negotiate. An agent that stands to benefit the most from forming a coalition usually acts as the coalition leader. A coalition leader negotiates bilaterally with multiple agents of its own type (buyer, seller or LP) to establish a sectoral coalition, i.e., a coalition of buyers, or a coalition of sellers, or LPs etc. The object of such negotiation is usually to establish how the coalition value, i.e., the financial benefits of collaboration might be distributed across the members of the coalition. Other issues that may be negotiated include the modalities of collaboration (e.g. how two smaller trucking companies might pool their transportation resources together) etc. The coalition leader then negotiates with sectoral coalitions in other sectors to establish a cross-sectoral coalition such as one involving buyers and LPs or one involving buyers, sellers and LPs. We note that these negotiations must occur within stringent time constraints, hence the duration of the negotiation process is itself a factor in the decisions made.

3. Related Work

Coalition formation is an active research area in multi-agent systems. In addition to analyzing stability and payoff distribution, researchers pay more attention to the formation mechanism, i.e., negotiation protocols among agents and the decision making, or reasoning, of individual agents. In the following we mention some previous work which overlaps with our proposed framework.

(Tsvetovat et al. 2000) studied the formation of buyers in university environment where students buy their text books in group. In their work, there was no delivery cost involved in the process of forming coalitions among buyers—which was different from our work. Li (Li et al. 2002) addressed the combinatorial auction in coalition formation. Buyers submit their requests to the mediator who will allocate the good from sellers to them. Goldman (Goldman et al. 2001) searched for a strategy where sellers selected the most profitable deal while buyers looked for the most satisfiable sellers. Again, the delivery cost was not taken into account in these two works. Kraus (Kraus et al. 2004) proposed a compromise strategy for distributing profits among sellers in order to form a coalition quickly. They found that agents who are willing to give away their profits actually earn more. We are looking forward to investigate in multi-level coalition formation, whether it is worthwhile to sacrifice individual payoffs in order to form coalitions.

(Breban et al. 2000) addressed coalition formation based on trust among agents. Trust is used as a mechanism to enforce agents to commit themselves to the jobs as parts of the coalition. We are yet to incorporate the trust issue into our future work. (Hyodo et al. 2003) addressed the optimal coalitions of buyers and sellers who are located in distributed sites. They deployed a genetic algorithm to search for the optimal share over the discount in a global optimization manner, whereas our work allows negotiation among agents. (Klusch et al. 2002) addressed problems in static coalition formation and proposed an algorithm for mobile agents to form coalitions under dynamic environment. Although allowing agents to form overlapping coalitions, there was only one step before agents could achieve their payoff. In our work, buyers, sellers and LPs need to form coalitions across sector in order to achieve payoffs. Sandholm (Sandholm et al. 1995) studied coalition formation of trucks in dispatch centres. Agents were rather altruistic than self-interested like in our work. Their goal was to find the optimal task allocation in order to maximize the company's profit. They assumed the coalition values existed as in cooperative games in characteristic function form, whereas our work allows agents to search for such values. There is no work in coalition formation, as we are aware of, that combines buying and delivery.

4. Coalition Formation Setting

We model a dynamic supply chain as a dynamic cooperative game. We refer to a coalition as a set of agents who are involved in delivering a set of goods to a set of end consumers. Agents are divided into three sectors: sellers, buyers and LPs. Their relationship is simple: buyers order goods from sellers and LPs distribute goods over a road network for them. A coalition is formed once two or more agents agree to cooperate. Firstly, agents from the same sectors can form primary coalitions. A primary coalition is a preliminary agreement among agents in order to increase their negotiation power as well as increase their individual payoffs. This kind of coalitions is loosely-coupled—its members can deviate to another primary coalition, which they believe is more advantageous. Primary coalitions can happen in several ways, e.g., two buyers agree to buy goods together, sellers agree to aggregate for their selling power, LPs agree to collaborate in order to minimize their costs or to reach their schedules. Agents seek other agents, who might help maximizing their secondary coalition value, in order to form primary coalitions. This helps agents maximizing their individual payoffs. The coalition value of a primary coalition is intangible. It is rather an opportunity of agents that they will achieve tangible payoffs in their secondary coalitions. Lastly, agents form secondary coalitions across the three sectors in order to deliver goods to end consumers, i.e., buyers. This is where agents can achieve tangible payoffs. Minimally, this kind of coalitions is composed of a buyer a seller and an LP.

4.1 Setting

Let $B = \{b_1, b_2,\dots, b_m\}$, $S = \{s_1, s_2, s_n\}$ and $L = \{l_1, l_2,\dots, l_o\}$ be the set of buyers, sellers and LPs respectively. Buyers order goods (which from this point onward we refer to as foods), $F = \{f_1, f_2,\dots, f_p\}$, from sellers. LPs distribute the foods over a road network, $G = \{V, E\}$, where V is a set of vertices and E is a set of edges, each of which connects a pair of vertices, for them. Each game lasts a number of time slots, $T = \{t_1, t_2, \dots, t_q\}$. The location of each buyer b, seller s, and LP l are specified by function $L_b : B \rightarrow V$, $L_s : S \rightarrow V$, and $L_l : L \rightarrow V$ respectively. These three functions are accessible to all agents. The communication cost c_c among agents is determined by the function $\mathcal{C}_C : V \times V \rightarrow \boldsymbol{R}^+$. At the beginning of each game, agents will be initialized with individual goals and constraints. A buyer has a demand for a food d, which is determined by function $\mathcal{D} : B \times F \rightarrow \boldsymbol{N}^+$, under a budget b, which is determined by function $\mathcal{B} : B \rightarrow \boldsymbol{N}^+$, and a due time t_d, which is determined by function $\mathcal{TD} : B \times F \rightarrow T \backslash t_q$. A seller can produce a food for a certain number p, which is determined by function $\mathcal{P} : F \times S \rightarrow \boldsymbol{N}^+$. The time it takes to produce a food is t_p, which is determined by function $\mathcal{TP} : F \times S \rightarrow \boldsymbol{N}^+ \times T$. The cost of producing a food is c_p, which is determined by function $C_P = F \times S \times \boldsymbol{N}^+ \rightarrow \boldsymbol{R}^+$. An LP is initialized with a load capacity l, which is determined by function $\mathcal{L} : L \times F \rightarrow \boldsymbol{N}^+$. The cost of delivery is c_d, which is determined by $\mathcal{CD} : V \times E \times T \rightarrow \boldsymbol{R}^+$.

4.2 Forming Primary Coalitions

4.2.1 Buyer to Buyer Negotiation

Buyers can form coalitions to share discount on prices and delivery costs. A buyer can join any appropriate coalition for discount on price and saving on delivery cost. The following is the protocol for forming primary coalitions among buyers.

1. Every buyer b sends a message $(b, (f, q, t), v, p)$, where b is the identifier of the agent, (f, q) is a food and its quantity, $v \in V$ is the location where the food will be delivered, p is the price, and t is the due time it wants the food to be delivered.

2. Any agent b_0 can think of forming a primary coalition of buyers. It selects a number of agents, who share a form of similarity.

3. Agent b_0 sends a message (*msg*, b_0, *f*, *q*, *v*, *t*, *p*, *x*), where *msg* is the message id, *p* is the price, and *x* is the expiry time to the buyers in its proposal list.

4. Any buyer *b*, who is satisfied with the offer, sends a message (*msg*, *b*, *ACK*, *x*) back to b_0 stating that it will wait for a confirmation until time *x*.

5. Agent b_0 sends message (*msg*, b_0, *ACK*) to inform all interested buyers that now the primary coalition has been formed.

Agent b_0 can then negotiate with sellers and LPs for forming a secondary coalition, i.e., to finalize the order with sellers and organize the delivery with LPs.

4.2.2 Seller to Seller Negotiation

Sellers can form primary coalitions in order to increase their selling power. They can use different strategies. Sellers can try to form coalitions in order to increase the volume of a particular food. They may also want to form coalitions with other sellers located in nearby geographical proximity. The following is the protocol for forming a primary coalition among sellers:

1. Every seller sends a message (*s*, (*f*, *q*, *p*, t_d, *v*)) to all other sellers.

2. Any seller s_0 can think of forming a primary coalition with other sellers. It selects a number of sellers, who might help increasing its selling power.

3. Seller s_0 sends a message (*id*, s_0, (*s*, (*f*), *v*), *x*), where (*f*) is a list of foods, to agents selected if they want to form a primary coalition of sellers.

4. Any seller, who is satisfied with the offer, replies with the message (*id*, *s*, *ACK*, *x*) and waits for the confirmation by time *x*.

5. Agent s_0 confirms that a primary coalition is formed with the message (*id*, s_0, *ACK*).

4.2.3 LP to LP negotiation

The profit of LPs depends on their traveling times and traveling costs in the road network. Hence, a common goal among LPs may be minimizing their traveling time and traveling costs. One way to achieve such a goal may be to form a primary coalition with other LPs, whose present locations *distributedly cover* the road network. By doing so, each LP will be traveling in a certain area. The *number of foods carried per distance* can increase.

1. Every LP sends a message (*l*, *ℓ*, *v*) to all other LPs.

2. Any LP l_0 can think of forming a primary coalition with other LPs. It selects a number of LPs, who might help minimizing cost and time of traveling.

3. LP l_0 sends a message (*id*, l_0, *v*, *x*), to agents selected if they would like to form a primary coalition.

4. Any LP *l*, who is satisfied with the offer, replies with the message (*id*, *l*, *ACK*, *x*) and waits for the confirmation by time *x*.

5. Agent l_0 confirms to its primary coalition members with the message (*id*, l_0, *ACK*).

4.2.4 Decision Making to Join Primary Coalition

Agents want to form primary coalitions in order to help forming secondary coalitions from which their payoffs will be derived. Agents consider the value of a primary coalition as the Quality of Coalition (QoC), which describes the likelihood to be successful in forming secondary coalitions. QoC can be described by a template, a vector of attributes, each of which is a quantitative value that is ideal for a coalition. Agents use their templates to filter improper agents. Let $X = \{x_1, x_2,\ldots,x_m\}$ be a set of attributes. Let $B = \{\langle L_1, U_1\rangle, \langle L_2, U_2\rangle, \ldots, \langle L_m, U_m\rangle\}$ be a set of lower bounds and upper bounds of quantitative attributes $x_1, x_2,\ldots,x_m$. A template is a vector $t = \langle q_1, q_2, \ldots, q_m, w_1, w_2, \ldots, w_m\rangle$, where q_i is a quantitative attribute and w_k is the weight for each x_k of *m* attributes. Any agent a_0, who wants to form a primary coalition, uses the attributes passed over in the first step of the negotiation to measure the distance between other agents and its templates. The closer distance signifies the more suitability for the coalition of the agents. The distance can be considered as the sum of the difference of each pair of corresponding attributes in the template and the agents' attributes. For each attribute, the distance should be 0 if the attribute's values are equal. Otherwise the distance is the multiplication of the difference between the values of corresponding attributes, and the weight for that attribute. Let y_j be the value of attribute *j* of the template, the distance between an agent and a template can be derived as follows:

$$d = \sum_{j=1}^{m} \mathit{Diff}(q_j, y_j) w_m$$

Where

$$\mathit{Diff}(q_j, y_j) = \begin{cases} \infty & \text{if } y_j > U_j \text{ or } y_j < U_j \\ \frac{q_j - y_j}{q_j - L_j} & \text{if } q_j > y_j \text{ and } y_j \text{ is } \geq L_J \\ \frac{y_j - q_j}{U_j - qj} & \text{if } q_j < y_j \text{ and } y_j \text{ is } \leq U_j \\ 0 & \text{if } q_j = y_j \end{cases}$$

Let us consider an example of how this mechanism works. Suppose there are four attributes, $X = \{f, q, p, t\}$, to describe a quality of primary coalition of buyers. Let $B = \{\langle 1, 10\rangle, \langle 10, 20\rangle, \langle 10, 30\rangle, \langle 0, 100\rangle\}$ be the set of upper and lower bounds for *f*, *q*, *p* and *t*, respectively. Let $T = \langle 1, 15, 20, 30, 1, 10, 1, 5\rangle$ be a template of buyer b_0, who is considering forming a primary coalition. There are two buyers, b_1 and b_2 being considered whether they should be invited to join the coalition by b_0 as possible coalition partners. Their attributes, achieved from the messages, are {1, 13, 18, 28} and {1, 17, 23, 34}, respectively. The distance between agent b_1 and template T is

$$\begin{aligned} d_1 &= (0 * \infty) + (2/5) * 10 + (2/10) * 1 + (2/300) * 5 \\ &= 0 + 4 + 0.2 + 0.33 \\ &= 4.53 \end{aligned}$$

The distance between agent b_2 and template T is

$$\begin{aligned} d_2 &= (0 * \infty) + (2/5) *10 + (3/10) * 1 + (4/70) * 5 \\ &= 0 + 4 + 0.3 + 0.57 \\ &= 4.87 \end{aligned}$$

Since 4.53 is less than 4.87, agent b_1 is obviously closer to the template than b_2. Hence, agent b_1 sits higher in the ranking table. Each agent has their own ranking table of preferred primary coalitions. It may decide to send an offer or decide to wait for some time to receive offers. If it receives an offer, which proposes a primary coalition that is similar to one of it's preferred ones, the agent can decide to join. If the agent decides to lead forming a primary coalition, i.e., either being b_0, s_0 or l_0, it has to make a decision about how many agents to be included in the coalition. Agents can use multiple templates for forming multiple primary coalitions. A buyer, for example, may want to buy multiple foods with other buyers, who are located in various places. Agents can also use multiple templates for forming a single primary coalition. An LP may want to form a primary coalition with other LPs such that each of them exclusively covers a certain area and all of them inclusively cover the whole area.

4.3 Secondary Coalitions

A secondary coalition is formed when a set of buyers agree to buy a set of foods from sellers and agree to have LPs deliver the foods for them. Any agent a_0 who leads forming primary coalitions represents its members to negotiate with other agents. A leading buyer b_0 of a primary coalition represents its members to negotiate on prices of the foods with a leading seller s_0 as well as negotiate for delivery costs of the foods with a leading LP l_0. The leading agents also have to negotiate with their coalition members for their final decisions. Agents who are not satisfied with payoffs they might achieve may decide to deviate from their present primary coalitions and try to reform the new ones.

4.3.1 Buyers to Sellers and LPs

Before a leading buyer b_0 negotiates, it collects information provided by its coalition members in order to create a price request. It then negotiates with leading sellers and leading LPs as follows:

1. Agent b_0 sends message $B2S(id, b_0, (f, q, t), p)$ to leading seller s_0s, where t is the available time.

2. Any leading seller s_0 who is interested then counsels with its coalition members present capability. Agent s_0 broadcasts the request to its members.

3. The member sellers evaluate their present capacities and reply with a message $S2S(id, b, (f, q, t), p)$ bidding for the job.

4. The leading seller may have to negotiate on food, quantity, time and price with member sellers with message $S2S(id, b, (f, q, t), p)$ until every member seller is satisfied and the total quantity, available time and price is satisfied with the request.

5. The leading seller s_0 accumulates the bids from its member sellers to create an offer. It then sends message $S2B(id, s_0, (f, q, v, t), p)$ back to b_0.

6. The leading buyer then can manage to negotiate for delivery with LPs. It sends message *B2L*(*id*, b_0, (f, q, v, t), (f_0, q_0, v_0, t_0), p), where (f, q, v, t) and (f_0, q_0, v_0, t_0) specifies job description for picking up from sellers and delivering the foods to buyers, to leading LPs.

7. Interested leading LP l_0s broadcast the message to its primary coalition members.

8. Member LP l, who is interested, bids for the task by sending message *L2L*(*id*, (f, q, v, t), (f_0, q_0, v_0, t_0), p) to its leading LP l_0.

9. The leading LP l_0 accumulates all bids from its members in order to create a proposal for the distributing job. It may have to negotiate over quantity, pickup location, delivery location, pickup time, delivery time, and price with its members.

10. Once it can create a reasonable proposal after reaching agreement with all members, it sends a message, i.e., proposal, (*id*, s_0, (f, q, v, t), p) back to b_0.

11. The leading buyer b_0 accumulates the proposals from the leading sellers and leading LPs and finds the best combination of a selling and an LP proposal. It then creates a proposal to its members and sends message (*id*, s_0, (f, q, v, t), p) to the members.

12. Members who are satisfied with the proposal send a message (*id*, s, *ACK*) to l_0.

13. Members who are not satisfied can negotiate over quantity, time and price by sending message (*id*, s, (f, q, v, t), p) back to the leading agent.

14. Once all member buyers are satisfied, the leading buyer then sends message (*id*, b_0, *ACK*) to the selected leading seller and LP.

15. The leading buyer, seller, and LP send message (*id*, a_0, *CONFIRM*) to their coalition members confirming that the secondary coalition has been formed.

LPs are to pickup the foods from sellers and deliver to buyers. Sellers and LPs get paid when the foods are delivered. The negotiation within and among primary coalitions can keep going until agents are satisfied or the time is over.

4.4 Decision Mechanism

In our setting, each agent has their individual reserve price. For any buyer b, the reserve price r_b is the maximum price he is willing to pay for acquiring a bunch of foods, i.e., including prices of foods and costs of delivery. For any seller s, the reserve price r_s is the cost c_p of producing foods plus the minimum profit it expects. For any LP l, the reserve price r_l would be the estimated cost of operation plus the minimum profit it expects. Let $\mathsf{B} \subset B$, $\mathsf{S} \subset S$, and $\mathsf{L} \subset L$ be a set of buyers in a primary coalition, a set of sellers in a primary coalition, and a set of LPs in a primary coalition, respectively. For a secondary coalition $\mathsf{C} = \{\mathsf{B}, \mathsf{S}, \mathsf{L}\}$, the reserve price of B is

$$r_{\mathsf{B}} = \sum_{b \in \mathsf{B}} r_b,$$

the reserve price of S is

$$r_S = \sum_{s \in S} r_s, \text{ and}$$

the reserve price of L is

$$r_L = \sum_{l \in L} r_l$$

The coalition value of a secondary coalition C is

$$V_C = r_B - r_S - r_L,$$

which is to be distributed among agents. Let P_S be the price sellers charge buyers. Let P_L be the price LPs charge buyers. The payoff for buyers in B is

$$U_B = r_B - P_S - P_L.$$

The payoff for sellers in S is

$$U_S = P_S - r_S.$$

The payoff for LPs in L is

$$U_L = P_L - r_L.$$

The price each agent uses to negotiate may be higher than their reserve prices. There are several solution concepts in coalition formation theory (Kahan et al. 1984), e.g., core, kernel, etc. Knowing the bidding price of every agent in its primary coalition, the leading agent may try to find a fair division of their coalition payoff by using the Shapley value (Straffin 2002) concept. Agents in the primary coalition may find that the shares offered by the leading agent are below their won reserve price. Hence they may have to deviate from their present primary coalitions.

5. Conclusion and Future Work

This paper proposes a model of agents-based coalitions in dynamic supply chains In our setting, agents take two steps: *i*) agents in each sector form loosely-coupled coalitions in order to decrease the complexity of the negotiation, and, *ii*) agents form coalitions across sectors in order to deliver foods to end customers. We propose a simple framework, which involves a negotiation protocol and a decision mechanism. The negotiation protocol allows thorough communication, i.e., buyers to buyers, buyers to sellers, sellers to sellers, buyer to LPs, and LPs to LPs. The decision mechanisms at this point are simple ones. They simply show how primary and secondary coalitions can be formed. In contrast to the study of coalition formation in game theory that only pays attention to the analysis of stability, coalition formation in multi-agent system is concerned with algorithms of decision-making and negotiation of agents. Since one of the important issues in supply chains is to minimize logistics costs, we aim to find a mechanism that helps buyers to manage controlling logistics process rather than leaving it to sellers.

We believe that with an efficient negotiation protocol and a decision making mechanism, the logistics costs can be reduced. The further step of our research is to concentrate on inventing such a protocol and evaluating it. We also have to consider the area of planning under uncertainty, e.g., the cost of travelling in heavy traffic, where the costs of logistics can hardly be estimated. To this end, approaches like Markov decision processes, Bayesian networks, CP-Nets, should be applicable. Furthermore, agents in such settings have to learn from the past and project it to forecast what will happen in the future. Efficient utilization of knowledge base helps agents perform better in dynamic coalition formation. We intend to implement a simulation based on this framework. We want to develop agents who are able to evolve strategies in order to enhance cooperation. We believe that the more agents cooperate, the better outcomes for agents in the long run. We want to explore how, under changing environment, agents can adapt their strategies and be successful at the end.

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