A Proposal of Middle-Agent Based Framework for Innovating A Business Model

Hiroki Nakagawa, Akihiko Nagai, and Takayuki Ito
Nagoya Institute of Technology
Nagoya, Japan
nakagawa@itolab.nitech.ac.jp

***Abstract*—In this paper, with a middle-agent based framework, we can expect to figure out a business model that is focused on distributors for win-win cooperation and collaboration by revealing the effect, the influence, and the requirement for consensus in cooperation and collaboration. Cooperation and collaboration help companies collect such resources as technologies, knowledge, information, and funds as well as creating new businesses and developing new products. Distributors can create good cooperation and collaboration by mediating between manufacturing and user companies. We give an example of the collaborative development of new products where a distributor mediated between maker and user companies. Application Specific Standard Product (ASSP), which is an LSI for specific applications, is attracting attention. To develop an ASSP, both semiconductor and user companies must agree on the functions that the ASSP has and how many ASSPs must be considered without disclosing secret information. In this paper, We modeled distributors in a collaborative development and implemented a tool for an agent-based simulation, in which we imagined a market where a product is developed, sold, and bought. We investigated the role of middle agents, distributors and how they affect the market. In addition, we proposed a framework for examining a new business model.**

***Keywords*-Middle Agent; Innovation; Business Model; MOT; Technology Management**

I. Introduction

In this paper, we propose a middle-agent-based framework to innovate a business model to promote consensus building among many companies. This framework is a tool to analyze what is needed for consensus building as well as the effect and influence of collaborative development, which is unclear in the real world. New knowledge about consensus building can be acquired with this framework. Win-win relations for many companies can be realized by promoting consensus building for multiple collaborative development among them.

Cooperation and collaboration help companies collect such resources as technologies, knowledge, information, funds as well as creating new business and developing new products. Cooperation and collaboration have difficulty building a consensus because most companies place excessive emphasis on profit.

In the semiconductor industry, semiconductor companies develop Application Specific Standard Products (ASSPs) in collaboration with user companies. The collaborative development of products enables them to accurately acquire a market's need and create new technology, But building a consensus is difficult because collaborative development with a user company causes misunderstandings over multi-issues intimately related to each business. With whom and how to build a consensus is an important problem in the collaborative development of products. Many researchers have discussed the methodology of consensus building without discussing who will manage it. For example, Imada pointed out that consensus building based on autonomy and individuality is more important than social integration by a central agreement and analyzed its structure and function without considering management behavior [3]. This situation is the same in the methodology of contracts. Even though Ito discussed consensus building, he concentrated on stakeholder's profits.

In the real world, most transactions among companies are one-to-one. Our paper focuses on consensus building in multiple collaborative development among many companies. In this paper, we utilize middle-agent-based framework to promote consensus building among many companies. The middle-agent model is proposed as one multi-agent system that consists of individual agents who are designed differently. Middle agents chiefly match agents and assign tasks. When we design a business model among many companies in the real world, they not only match and adjust in collaborative development but also promote and innovate a business model (Section 2).

In this research field, Kato focused on group decision making for a consensus building process, developed a support tool, and evaluated it, but didn't apply it to any concrete example [5]. Our approach is meaning at this point. This paper is organized as below. The next section shows a concrete example in which a semiconductor distributor mediated between semiconductor and user companies while developing an ASSP. The third section shows a model for negotiating collaborative development transactions. The fourth section shows an agent-based simulation result from that model. Finally, the last section provides a conclusion. We participated directly in this project and interviewed all related parties to emphasize objectivity. We asked many related parties the same questions to get exact information and collected data from websites and documents.

II. Pachinko manufacturer needed a high-performance graphic LSI

In this section, we explain the background of a pachinko manufacturer who needed a high-performance graphic LSI.

1) Each pachinko manufacturer's approach to graphic LSIs: By 1998 in the pachinko market, digital pachinko parlors with liquid crystal displays had become the mainstream. Such new displays attracted many female customers to the games because they provided a sense of fun that previous pachinko parlors had lacked. Pachinko manufacturers noticed that graphic LSI added an important element to enhance the sense of fun. To solve this problem, Company B, a large pachinko manufacturer, developed a graphic LSI in collaboration with a semiconductor company.

2) B's approach to graphic LSI: First, Company B tackled the development of its own graphic LSI. It approached Company A, a semiconductor distributor, who cooperated with AXELL, a semiconductor company with image processing technology for animation and achievement. A proposed that the three parties develop an ASSP together. B agreed and started development, which was discontinued soon. A proposed the productization of a graphic LSI as an alternative to the development of ASSP to AXELL and B again. B abandoned its graphic LSI but still wanted it, so they decided to participate in the productization of a graphic LSI.

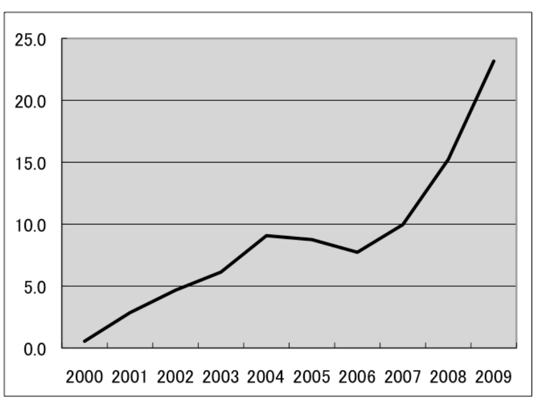

Figure 1. Sales of graphic LSIs for pachinko parlors

This LSI sold rapidly, and in 2009, its sales achieved 23% of all sales. It contributed to A's achievement. In this paper, we analyze Company A's approach to the graphic LSI.

A. Why did AXELL tackle the productization of a graphic LSI?

This subsection gives AXELL's background of the productization of a graphic LSI.

1) Four reasons why the productization of a graphic LSI for pachinko was decided : AXELL had many reasons for producing a graphic LSI with their own image processing technology, which is their strength. First, the market scale of graphic LSIs was expected to expand. Second, the prices of products were expected to increase if they included graphic LSIs with high functionality and performance. Third, at that time, the market had no graphic LSI only for pachinko parlors. Fourth, semiconductor companies had a negative attitude toward the pachinko market. For these reasons, AXELL, a small venture company, entered the pachinko market.

B. Why did the two parties fail to build a consensus?

Minimum demand quantity and demand function are two reasons why AXELL and Company B failed to build a consensus.

1) The reason why minimum demand quantity prevented a consensus : AXELL and B had to agree about minimum demand quantity and demand function. They failed to agree about the former. For AXELL, minimum demand quantity is the quantity that is replaced with these costs. For B, minimum demand quantity is the amount of graphic LSIs that it could buy.

Since Company B didn't need to cover the development and production costs, AXELL had to solve this problem. B could buy not more than 50,000 graphic LSIs. The other hand, AXELL had to sell not less than 300,000 graphic LSIs annually for FUJITSU to produce them. B's quantity was 50,000 and AXELL's quantity was 300,000. Building a consensus was impossible because of the huge disparity between these two figures.

2) The reason why demand function prevented a consensus from being built : Let us think about demand function next. Functions can be classified into three categories by how much they are demanded: required, convenient, and specific. "Must have" is an essential function for graphic LSIs. "Nice to have" is a recommended function but it isn't essential. "Specific" is a function that B particularly demanded. When producing the ASSP, there was difference in the demand function between AXELL and Company B. B demanded too many functions. Generally in the productization of ASSPs, semiconductor companies give priority to "required" functions and avoid "convenient" or "specific" functions because of the high cost of development and productization. Company B demanded the following functions: ① 3D, ②enhanced sprite efficiency, ③electrostatic protection, ④high data compression rate, ⑤D-RAM, ⑥ROM, and ⑦BGA package. B considered all of these functions "required" and demanded all of them. On the other hand, for AXELL, demand functions were those that each pachinko manufacturer recognized as "required." AXELL didn't know which functions were "required." B wanted all functions; AXELL didn't know which function was demanded. They couldn't build a consensus. Table I summarizes this situation. The huge difference in their minimum demand quantity and

Table I
DIFFERENCE IN MINIMUM DEMAND QUANTITY AND DEMAND FUNCTION

Item	Company B	AXELL
demand quantity	Total 50,000/year	Total 300,000/year
demand function	wanted all functions all "required" 7 essential functions	want to classify functions realize "required" surely didn't realize "nice to have" didn ' t realize "specific" didn't know essential functions

demand function prevented them from building a consensus. Failing to realize the productization of the ASSP is undesirable. AXELL couldn't develop a graphic LSI and B couldn't get a high-performance graphic LSI.

C. Participation of a semiconductor distributor in consensus building

Next we explain how a semiconductor distributor solved the problem and help them build a consensus.

1) Semiconductor distributor mediates to build a consensus : In this example, we summarize how a semiconductor distributor filled the gap in the minimum demand quantity and demand function over which they failed to agree. Concerning minimum demand quantity, since Company A thought that it could sell the graphic LSIs for pachinko to other companies, not only Company B, they contracted to buy 300,000 LSIs with AXELL. This proposal filled the gap in the minimum demand quantity between the supplier and the consumer. For its demand function, Company A inspected 20 pachinko manufacturers, whose customers classified the functions demanded by Company B, and extracted the "required" functions. This proposal, which was based on their investigation about "required" functions, was important for AXELL who now recognized the functions that they should develop. This investigation led to an LSI that contained functions that Company B didn't want, but it agreed with A's proposal anyway. The investigation also showed that ⑤, ⑥, and ⑦ were "specific" and unnecessary functions because they caused a lack of internal memory if the contents become complex. They also cost more and needed high technology to mount the substrate. Due to mediation by A, the semiconductor distributor enabled AXELL and B to fill the gap in the minimum demand quantity and demand function and to build a consensus. A suggested that graphic LSIs would produce competitive power for all pachinko manufacturers when A sold them. Many competitors could get the same high-performance graphic LSI as B but it was worth developing an LSI with "required" functions because they could differentiate their product from others by the contents. The "required" functions secondarily simplified procurement for pachinko manufacturers and lowered market prices. Greater sales increased the profits for AXELL and A.

III. TRANSACTION MODEL IN PRODUCT DEVELOPMENT

A. Product market

In this paper, we suppose a market where suppliers s, users b, and distributors d develop products l and deals with product g. Product g is dealt with by two parties, like the good in [10], but it is different from the good because the product doesn't exist initially. The product results from negotiation with a supplier and a user. The product's functions are decided in negotiation, so the same products aren't always distributed. In the semiconductor example, the product is a graphic LSI and the function is a feature to realize 3D and to avoid block-noise. The number of defective LSIs increases if their size exceeds 5mm^2. An IP core must be designed whose size minimizes defective LSIs. The product can't have all functions because of physical and economical limits. For example, if the product has not less than three functions, it is denoted by $g = (f_1, f_2, f_3)$ with function f. The product's functions are decided by the suppliers, users, and distributors.

B. Agent

Suppliers sell products to users. Suppliers have technologies to develop functions mounted on products. Each supplier can develop different functions. They have secret information about functions they can develop and each function's price. This price is calculated by the sum of cost $c(f)$ and supplier's profit $p_s(f)$. The supplier's utility from product g is profit $u_b(g)$ made by selling the product and is calculated by Eq. 1:

$$u_s(g) = p_s(g). \quad (1)$$

Users buy products from suppliers and have secret information about the functions that they demand and the valuation for function v_b. They also have limitations on maximum demand quantity. A user's utility from product g is different from the product's valuation and its price and is calculated by Eq. 2:

$$u_b(g) = v_b(g) - c(g) - p_s(g). \quad (2)$$

Distributors play the role of both suppliers and users. They buy products from suppliers and sell products to users. They mediate with suppliers and users to build consensuses. For this role, they collect secret information from suppliers and users. From suppliers, they gather technical information about functions to be developed and demand information from users about functions they need. In direct negotiation with suppliers and users, they don't disclose secret information. When a distributor mediates a negotiation, even if a supplier or a user tells the distributor its secret information, the information doesn't directly benefit the distributor. The information benefits the distributor only when the distributor has a successful negotiation. The distributor hence can collect secret information. Based on their technical and demand information, distributors help suppliers and users agree on a product's functions and quantity. For example, when arranging functions, distributors match user demands and supplier technology and consider which functions benefit them. When arranging quantity, they contract to sell products to many users if they fail to build a consensus because of the difference in supplier and user quantities. Distributors add their profit to the product's price and sell it. The margin is the distributor's utility:

$$u_d(g) = m_d(g). \tag{3}$$

The utility each agent gets is uq when dealing with q products.

C. Transaction process

Users propose their demand functions and negotiate with suppliers. Distributers mediate the negotiation with two parties to help build a consensus We show three kinds of interaction between different agents to explain the actions of suppliers, users, and distributers in this market.

1) Suppliers and users: We suppose a case in which a user directly negotiates with a supplier, arranges a product's functions, and handles it. Users have valuation v_b for each function. The higher the valuation of v_b is, the more the user wants the function. If v_b is zero, the user doesn't really want it . Users propose products with the functions they want to suppliers. In contrast, suppliers present the proposed product prices. This price is the sum of the development cost of all functions in product c and supplier's profit p_s. Users buy the product by price, and the transaction succeeds with probability $p(q_s, q_b)$, which is denoted by the supplier's minimum demand quantity q_s and the user's maximum demand quantity q_b if the user's valuation exceeds the price presented by the suppliers. Compared with supplier's minimum demand quantity q_s, the bigger user's maximum demand quantity q_b is, the bigger probability $p(q_s, q_b)$ becomes. That is, building a consensus is difficult unless the user buys as many products as demanded by the suppliers. The negotiation breaks down if the valuation is smaller than the price.

2) Suppliers and distributors: Consider the case in which suppliers interact with distributors. Suppliers disclose their secret information to distributors. Such secret information is their technology about which functions they can mount on the product and how many products they demand. With this information, a distributor promotes a negotiation that benefits the suppliers when distributors mediate between suppliers and users. Distributors are third parties who profit by effecting deals with suppliers and users. Suppliers tell distributors their secret information because the distributors must produce a proposal on which both parties agree to get a profit.

3) Users and distributors: Now we examine a case between users and distributors. Distributors act as suppliers for users. In practical terms, this means that users propose products to develop, not to suppliers, but to distributors. Distributors check the user's demand information and the supplier's technical information (each at function prices) to select a supplier as a trading partner. They consider which functions the product should have and propose them. The selected supplier presents its price to the distributor, based on the functions that the proposed product has. Distributors also add profit to the price and present this added price. The transaction succeeds with probability $p(q_s, q_b)$ if the user's valuation exceeds the new price. Also between users and distributors, the transaction depends on the supplier's and the user's quantities. Distributors can search for other users in reference to each user's demand information. Then they help build a consensus by forging deals over the same product with other users (Fig. 2).

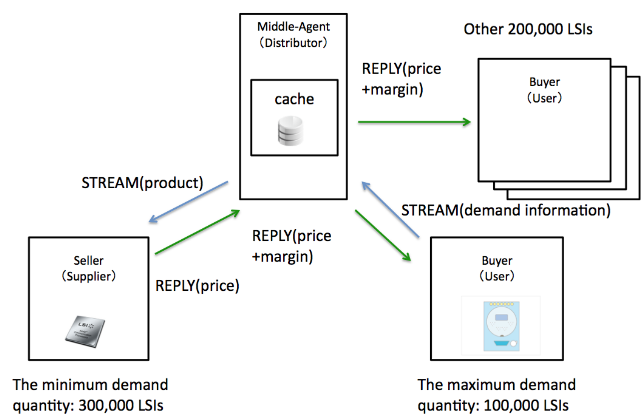

Figure 2. Model of distributor mediation

D. Proposal for product function by distributors

Distributors propose product functions to ask users about their demands and respond with supplier's technology. The strategy proposed by product distributors affects consensus building and each agent's utility. In the real world, distributors employ various strategies. In the semiconductor market, the semiconductor distributor proposed an LSI that has the functions wanted by many users and sells them to the semiconductor company after agreeing with the quantity and the functions. On the other hand, a distributor might propose a product that only responds to the user ' s demand. In our simulation, distributor agents used the following strategies:

A General demand
In this strategy, the distributor considers general demands based on demand information that it collected to find the combination of functions that minimize the sum of each user's valuation and

proposes product g_a that satisfies Eq.4:

$$g_a = \text{argmax}_g \sum_b v_b(g). \tag{4}$$

B Customer demand
The distributor finds the combination of functions that maximize the customer's user's valuation and proposes product g_b that satisfies Eq. 5:

$$g_b = \text{argmax}_g v_b(g). \tag{5}$$

C Myopia
In this strategy, the distributor finds a combination of functions that maximizes its own margin and proposes product g_c that satisfies Eq. 6:

$$g_c = \text{argmax}_g m_d(g). \tag{6}$$

D Hyperopia
Here, the distributor finds a combination of functions that maximizes the sum of the utilities of the supplier and the user for whom the distributer is mediating and proposes product g_d that satisfies Eq. 7:

$$\begin{aligned} g_b &= \text{argmax}_g \{u_s(g) + u_b(g)\} \\ &= \text{argmax}_g \left[v_b(g) - \{c(g) + p_s(g)\} - p_s(g)\right] \\ &= \text{argmax}_g \left(v_b(g) - c(g)\right). \end{aligned} \tag{7}$$

IV. Simulation

A. Setting

We simulated a model in which suppliers, users, and distributors develop and deal with products g, research the effect on distributors, distributors, and consider the result. The simulation tool was developed in Java. In the simulation, we randomly paired the number of agents * 100 times. The pair consists of two different kinds of agents. For example, there is no pair of a supplier and another supplier. We ran 2,000 simulations and examined the average. The following are the fixed parameters: 100 suppliers, 100 users, 20 functions, the maximum number of functions the product has, the number of functions each supplier can develop, and the number of functions users can demand. Distributors use the general demand strategy and search for a supplier who can develop the product most cheaply from the collected information and mediate a transaction. In this simulation, the other agent parameters include supplier's and user's secret information and the distributor's margin.

B. Simulation results

1) Effect on distributors: Fig. 3 indicates the utility obtained by each agent from the product transaction by the number of distributors. The horizontal axis represents the number of distributors and the vertical axis represents the utility values. Suppliers, users, and distributors got higher utility values when distributors were involved. As the number of distributors increased, the higher the utility value increased of the suppliers and users, but the distributor's utility value decreased as the number of distributors increased. The average agent utility values increased because the increasing rate of the supplier's and the user's utility values exceeded the decreasing rate of the distributor's utility value.

Distributors increase the total profit. The distributor's utility value decreased because the number of distributors increased reflects competition among distributors . Users can only make a deal with a supplier who has the technology to meet their needs, and suppliers are in the same situation. Trading partners are hampered to some extent if suppliers and users make a deal. In contrast, distributors can get a profit whoever they mediate if they build a consensus. Suppliers and users don't intend to develop another product and make a deal once they have satisfied the quantity condition. Therefore, the utility value average of the distributors drops because distributors get less profit as the other distributors gets.

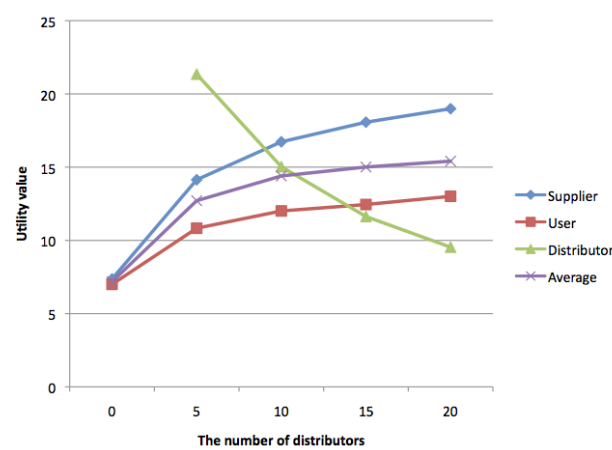

Figure 3. Each agent utility

Fig. 4 shows the number of consensuses built by the number of distributors. The number increased when distributors existed. The more distributors that existed, the more consensuses that were built.

The number of consensuses decreases when a supplier and a user negotiate directly without mediation as the number of distributors increases. Distributors collect information from suppliers and users. Distributors next mediate by matching a supplier with the technology to meet a user's need with the user. A supplier and user can pair off without mediation but the effect on mediating takes precedence over direct negotiation and builds a consensus.

2) Examining function: Table II indicates the general demand for functions developed in products by each case

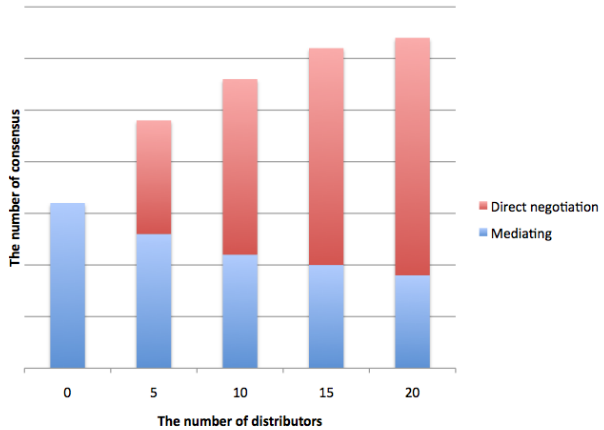

Figure 4. Number of consensuses

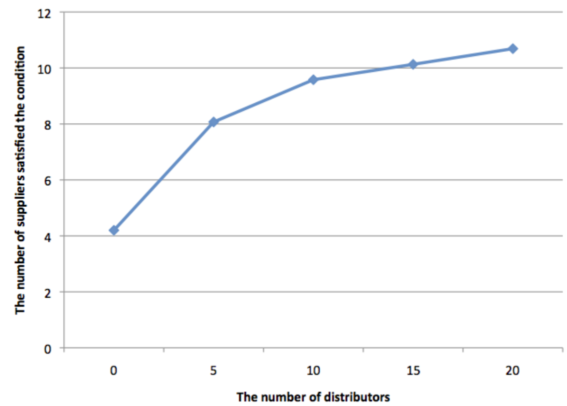

Figure 5. Suppliers who satisfied the demand quantity

of negotiation. The general demand is calculated by the sum of all user valuations for the functions. The general demand when a distributor mediates is higher than when a user directly negotiates with a supplier. Products, which have more general demand, probably have more ”required” functions that can be bought by many users.

Table II
GENERAL DEMAND FOR PRODUCTS

Case of negotiation	General demand
direct negotiation	3.92
mediation by distributor	4.09

3) Examining quantity: Fig. 5 shows the number of suppliers who dealt with as many products as the minimum demand quantity, which is the quantity to produce. The horizontal axis represents the number of distributors, and the vertical axis represents the number of suppliers who satisfied the condition. This number increased as the number of distributors increased. This result clearly suggests that broadening the market by distributors is effective.

4) Examining distributor strategies: One important role of distributors is proposing functions for products, based on the information collected from suppliers and users. Here, we simulated which proposal strategy benefits distributors or all agents and the character properties of each strategy. The result without a distributor is shown for comparison. In the simulation setting, the number of distributors is fixed to 5, and the other parameters are the same as above. Each strategy is shown as follows: A: General demand, B: Customer demand, C: Myopia, and D: Hyperopia.

First, we compare strategies A and B. The supplier’s utility value is higher in A, and the user’s utility value is higher in B. The distributor of strategy A emphasizes many user needs to broaden the market for the supplier. Therefore, the distributor probably isn’t concerned about customer user needs, so the supplier’s utility value is higher and the user’s one is lower in strategy A. The distributor of strategy B only considers the customer user need, which is the product that contains ”specific” functions so that the market becomes narrower. The supplier’s utility value is lower and the user’s is higher in strategy B.

The distributor of strategy C can’t match suppliers and users because they behave selfishly. As a result, they can’t help build a consensus and the utility value of all agents decreases. This situation is the same as having no distributor. In contrast, the distributor of strategy D emphasizes the profit of both the supplier and the user without considering their profit to simplify building a consensus; the distributor’s utility value also increases. The result is indicated in Fig. 6.

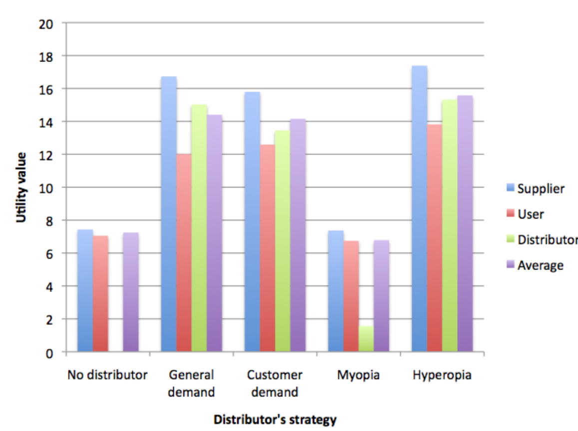

Figure 6. Agent utility by distributor strategy

5) Impact on secret information: In this simulation, we examine how the information that distributors collect from supplier's technology and user's demand affects negotiations. Originally, the information was collected from suppliers and users during the transaction. But in this simulation, we gave the distributors the initial information about all suppliers, all users, or both at the beginning to examine the impact of the quantity of information and on what kind of information.

Fig. 7 indicates the utility value of each agent based on the initial information. We assumed that the utility value of each agent increases when distributors have information about both suppliers and users. In fact, the utility value is highest when distributors have only the supplier's information.

User information seems to inhibit profit. Distributors exploit user information to sell products to many users. Fig. 4 also shows that consensuses increase as distributors broaden the market. Therefore, the average profit per transaction decreases instead of broadening the market. By selling the same products to many users, distributors have no chance in the future to sell suitable products to users who already have them; the total utility value falls.

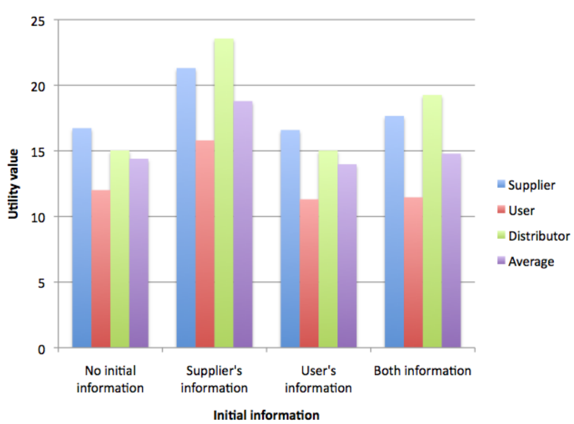

Figure 7. Agent utility based on initial information

V. Conclusion

In this paper, we focused on a middle-agent solution for consensus building with cooperation and collaboration. We proposed a transaction model of product development and ran simulations with it based on a concrete example where a semiconductor distributor mediated the collaborative development of ASSP. The model mediated by distributors as middle agents is a usable framework for increases in the utility values of each agent and builds consensuses when middle agents behave hyperopically. Under this condition, the average profit per transaction decreases.

References

[1] Akihiko Nagai and Koji Tanabe, "Senryakujoho no kyoyu katsuyo niyoru kyodo innovation -AASP gata system LSI kaihatsu no jire," The Development Engineering Society of Japan, vol. 30, 2, pp. 133-142, 2011.

[2] Akihiko Nagai and Koji Tanabe, "Shijo to gijutsu wo tsunagu handotaisyosya no enabler kino," Japan Society for Intellectual Production, vol. 6, 1, pp. 9-14, 2009.

[3] Takatoshi Imada and Takehiro Inohara, "Syakairiron ni okeru goikese no ichizuke -syakaitogo kara syakaihensyu he," Goikesegaku, Keiso Shobo, pp. 17-35, 2011.

[4] Hideshi Ito, "Keyaku no keizairiron," Yuhikaku, 2004.

[5] Naotaka Kato, Masahiro Nakajo, and Susumu Kunifuji, "Goikese process wo jushisita group ishiketteishien system no kaihatsu," IPSJ Journal, 1997, vol. 38, nos. 12, pp. 2629-2638.

[6] Parsons,T, and Masamichi Shinmei, "Politics and Social Structure", New York: Free Press, Seishin Shobo, pp. 1973-1974, 1969.

[7] Takehiro Inohara, "Goikesegaku", Keiso Shobo, pp. 1-14, 2011.

[8] Fisher. R, Ury. W, and Bruce, "Getting to Yes", Negotiating Agreement Without Giving In; Second Edition, Penguin, 1991.

[9] Koji Sumida, "Senryaku teki kosyo to kosyogaku", Patent 2005, (58)8, 5-13, 2005.

[10] Itai Yarom, Jeffrey S. Rosenschein, and Claudia V. Goldman, "The Role of Middle-Agents in Electronic Commerce", IEEE Intelligent Systems, vol. 18, November 2003.

[11] Amy R. Greenwald, and Jeffrey O. Kephart, "Shopbots and Pricebots", Proceedings of IJCAI '99 (International Joint Conferences on Artificial Intelligence), July 31- August 6, 1999, Stockholm, Sweden.

[12] J. Sairamesh, and J.O. Kephart, "Price Dynamics and Quality in Information Markets", Decision Support Systems, vol. 28, nos. 1-2, Mar. 2000, pp. 37-47.

[13] K. Decker, K. Sycara, and M. Williamson, "Middle-Agents for the Internet", Proc. 15th Int'l Joint Conf. on Artificial Intelligence (IJCAI97), Morgan Kaufmann, 1997, pp. 578-583.