Information Supply Chain: A Unified Framework for Information-Sharing

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Abstract. To balance demand and supply of information, we propose a framework called "*information supply chain*" (ISC). This framework is based on supply chain management (SCM), which has been used in business management science. Both ISC and SCM aim to satisfy demand with high responsiveness and efficiency. ISC uses an information requirement planning (IRP) algorithm to reason, plan, and satisfy needers with useful information. We believe that ISC can not only unify existing information-sharing methods, but also produce new solutions that enable the right *information* to be delivered to the right *recipients* in the right *way* and at the right *time*.

1 The Information Supply Chain Framework

Information-sharing refers to activities that distribute useful information among multiple entities (people, systems, or organizational units) in an open environment. Sharing information should consider four questions: 1) *what* to share, 2) *whom* to share with, 3) *how* to share, and 4) *when* to share. Better answering these questions can greatly improve information-sharing results: avoiding overload or deficiency, reducing sharing cost, and being more responsive. To address those questions and achieve better information-sharing results, we propose a framework called "information supply chain" or ISC.

The ISC framework is based on studies of supply chain management (SCM), which has been widely used in management science. A supply chain fulfills its customer's demand by a network of companies, mainly including suppliers, manufactures, and distributors. Fig. 1a shows a typical supply chain. A supply chain has two primary targets: to balance demand and supply and to improve efficiency and responsiveness. These are also the primary goals for sharing information. We, therefore, envision that the well studied SCM framework can work for information-sharing.

Similar to a supply chain, an information supply chain[1] (ISC) fulfills users' information requirements by a network of information-sharing agents (ISA) that gather, interpret, and satisfy the requirements with proper information. Fig. 1b shows an information supply chain.

[1] An ISC is different from the information flow of a supply chain.

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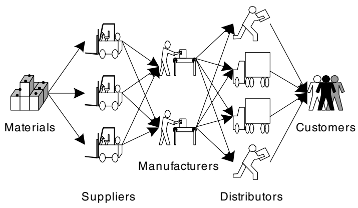

Fig. 1a. A typical supply chain

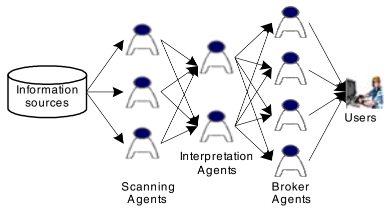

Fig. 1b. An information supply chain

Develop ISC from SCM

Developing the ISC framework requires understanding information-sharing problems, defining terms, developing methods, and choosing evaluation criteria. First, we examine if the SCM problems fit the problems of information-sharing. SCM always faces a problem to balance demand and supply. Unbalanced demand and supply leads to poor supply chain performances: either high cost due to over supplies or poor customer service due to stock outs. Information-sharing has the same problem: unbalanced demand and supply can cause either information overload or deficiency. The ultimate goal of both ISC and SCM is to make the demand and supply balanced.

Second, we collect terms that can be used to describe concepts in the ISC framework. Basic activities or objects in SCM such as purchase, sales, product, supplier, customer, or warehouse are comparable to those in ISC: query, inform, information, supplier, requester, or knowledge-base. Some concepts in SCM even suggest complex ideas for handling information-sharing problems. For example, bill of materials (BOM) lists the components needed to produce one unit of a product. Checking each component's availability can reveal the shortage for desired productions. Fig. 2a shows a BOM for a computer in a tree structure. If we have a main-board, a CPU, a monitor, and a keyboard, we need a hard-disk to assemble a computer.

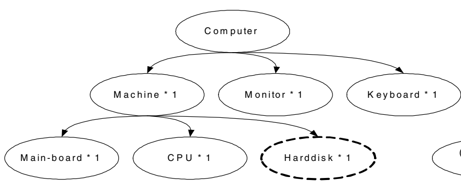

Fig. 2a. A BOM tree

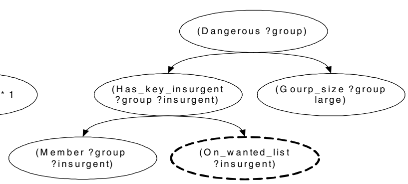

Fig. 2b. An IDR tree

We can find similar composition or dependency relationships among information. For example, implied information depends on one or more sets of supporting information or evidences, each of which may further depend on their own evidences. Such dependency relationship is called information dependency relation (IDR), which can be represented as a goal tree. Fig. 2b shows an IDR tree that illustrates intelligence analysis. Each node in the tree corresponds to the application of an antecedent-consequent rule[2]. Suppose a group is large and its members are known. Diagnosing the IDR can identify the missing information— “if the members are on the wanted list”.

Furthermore, warehouses, machines, or vehicles have capacity limitations for material storage, production, or transportation. Information-sharing agents have capacity limitations in a similar way: they have limited memory, reasoning power, or communication bandwidth. Besides, human users have grater cognitive limitations than agents have. People can only process very limited amount of information, thus they are easily overloaded by information from poorly designed systems.

After developing the concepts, we can adopt business models to handle information-sharing problems. For example, vender managed inventory (VMI) is a business model that specifies venders to manage their customers’ inventories. After a customer sets its demands over a period of time, the vendor monitors the customer’s stock and decides to refill when the stock level is low. It is an effective model that enables a company to focus its attention to customer service. We can adopt VMI model to information subscription, in which a provider updates its subscribers about any new or changed information. By subscription, a user can save time on queries and spend the time on processing information. We call subscription a counterpart of VMI. Other business models that have no counterparts for information-sharing can suggest new ways of sharing information.

Finally, we evaluate information supply chains by two criteria that are used to evaluate material supply chains: fill rate and total cost. Fill rates measure responsiveness— the more demands is fulfilled, the better the performance. Total cost measures efficiency by considering numbers of actions for seeking or sharing information. Fill rate and total cost are different from precision and recall, two criteria that are used for evaluating information retrieval systems. In the ISC framework, precision and recall can be used as “quality control” — to evaluate how well the provided information satisfies requirements.

ISC Differs from SCM

ISC differs from SCM. SCM deals with the flow of materials, while ISC deals with the flow of information. When we borrow strategies and methods from SCM to ISC, the difference between material and information should be considered. Quantity is used to measure material requirements. One material cannot fulfill demands from two. In contrast, we cannot use quantity to describe information. A piece of information can fulfill all demands about this kind of information, no matter how many requests are about it. Furthermore, material handling such as ordering, producing, packing, and shipping, differs from information processing such as query, observing, and transforming. Finally, materials have values, which can be determined in a market, whereas no market exists for information exchange. Although material differs from information in many ways, we believe that concepts, goals, methods, and philosophy of SCM can greatly improve information-sharing results.

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[2] We use logical rules as an example for IDR. However, IDR can also be used to capture other dependences such as the aggregative or selective relations among views and data sources.

Information Requirement

To balance demand and supply, an ISC should manage well information requirements. An information requirement (r) specifies what is required (p), who need it (a), how to respond (m), and when it is needed (t) — formally denoted as $r=<p,a,m,t>$. What is required (p) specifies both information type and size limit of expected results. An agent can fulfill a requirement if it knows information i that can satisfy p. How to represent i or p is relevant to problem domains. For example, p can be either a logical condition or a SQL query statement. Likewise, i can be either a logical proposition or a database record. In addition, p also includes a size limit, which specifies a maximum number of results that the needer can process. An agent should be clear about what is required so that it can satisfy the requirements with both the right type and the right amount of information.

Who need it (a) specifies a requestor and a needer. The requestor may be a different agent from the needer. Agent a_1 may request certain information from a_2 for agent a_3. a_1 is the requestor; a_3 is the needer. The difference between requestor and needer has been incorporated in current business practice for a long time: a sales order normally specifies a sold-to party who placed the order and a ship-to party who get the products. Yet current communication methods have overlooked the deference. They simply specify a requestor or an initiator without explicitly specify who the needer is. This makes an agent unable to identify duplication of information requirements that are from different requestors.

How to respond (m) specifies a protocol (m) such as "one-time query", "third-party subscribe" or "protell" [4]. Each protocol specifies how a provider interprets requirements, and how the provider interacts with other agents such as needers or requestors. For example, if an agent subscribes certain information, the provider should update the information regarding to changes. Including protocols in requirements allows information to be shared in the right way.

When it is needed (t) specifies a time condition such as "before certain time", "as soon as possible", "at certain time", or "periodically". Most information requirements may choose "before certain time" or "as soon as possible". Nevertheless, if a requester chooses subscribe, the requestor should choose "periodically" as its time condition. Whether or not a provider satisfies the time conditions can be used to evaluate its service quality. In that way, we can improve an information supply chain's performance by satisfying time conditions.

Information requirements come from three sources: direct requests, collaborative sharing of requests, and anticipations. An agent can request certain information by directly asking or subscribing. Such requests generate information requirements immediately. After the agent created a new request, it may forward it to other agents who can provide the information or seek information by investigating evidences, which may generate new requirements. Additionally, an agent can anticipate other's needs according to their mutual beliefs [1]. The total size limits of all information requirements should be less than the needer's information processing capacity so that the needer will not be overloaded.

The ISC framework can increase demand visibility. Information demands, in current research, are often implicit or incomplete. Demands are often hidden in assumptions, queries, or protocols. This makes it difficult to address the four questions: what to share, whom to share with, how to share, or when to share. With the ISC framework, it is easy to organize, analyze, plan, and fulfill information requirements, because it makes the requirements explicit and complete. We believe that better demand visibility can make information-sharing systems more responsive without causing information overload.

Information Requirement Planning (IRP)

In an ISC, planning and satisfying information requirements should be collaborative. Material requirement planning (MRP) proposes how to satisfy material requirements by considering type, quantity, and time of the requirements. According to the BOM and available materials, MRP can determine any shortages and creates the appropriate procurement or production plans. On the basis of MRP, we developed information requirement planning (IRP) for proposing plans to satisfy information requirements. IRP determines missing information according to the information dependency relation (IDR) and available information. IRP, then, creates information seeking plans accordingly. In addition, SCM uses collaborative planning methods to prevent unstable demand forecast and supply problems, known as “bullwhip” effects. Through collaboration, business partners create a common plan on how to satisfy consumers’ demand across the supply chain. This avoids redundant or deficient supplies. We can apply the same principle in ISC management. Agents can avoid duplications on anticipating, finding, or sending information through collaborations.

2 ISC Unifies Existing Methods

The ISC framework serves as an information-sharing platform regardless of complex information contents. The framework is general enough to manage various information-sharing activities, from scanning and interpretation to information delivery. Many existing information-sharing methods can be unified and incorporated into ISC by matching a counterpart method in the SCM framework. For example, FIPA “Query Interaction Protocol” [2] specifies how to handle a query between an

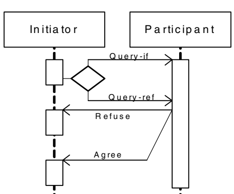

Fig. 3a. FIPA Query

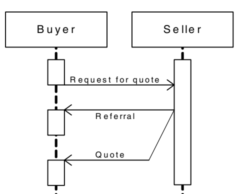

Fig. 3b. PIP FRQ

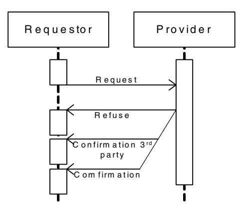

Fig. 3c. ISC Query

initiator and a participant as shown in Fig 3a. We can find a counterpart in SCM, such as PIP-3A1 (Request Quote as shown in Fig. 3b) from Rosettanet [3] in which a seller can choose to confirm a request or refer other suppliers if it cannot satisfy the request. It is easy to notice that the referral option is ignored in FIPA's specification. We thus can extend the current query protocol to incorporate the choice of referring alternative suppliers as 3rd party query confirmation (shown in Fig. 3c). Similar to the query interaction protocol, ISC is capable of unifying many other existing methods such as subscription, third-party subscribe" and "protell" [4].

The ISC framework can also lead to new solutions for information-sharing because years of research and practice in supply chain management can suggest overlooked problems, concepts, methods in the field of information-sharing. For example, Just-in-Time (JIT) is an efficient supply mode that aims to maintain high volume productions with minimum inventories (raw materials, work-in-process, or finish goods). Successful JIT productions depend on close collaborations with suppliers. The JIT philosophy, "to avoid over supply", reflects a goal of information-sharing — to avoid information overload. We thus propose using the JIT method to handle situations when agents/users are overloaded with frequently changed information. For example, suppose Tom lives in New York. He needs go to London for a conference in one month. He wants to check weather conditions before he leaves. It would be appropriate to pass the local weather forecast of London to Tom just before he leaves, as specified in JIT. Other methods are inappropriate. If Tom requests a forecast now, the information will become obsolete at the time when he leaves. A JIT request is the most appropriate approach because a) the information will not become obsolete and b) Tom will not get overloaded by irrelevant forecasts. The JIT method is suitable for requesting changing information such as weather forecasts, locations of moving objects, exchange rates, prices, and so on.

3 Conclusion

The goal of ISC is not to give a complete set of solutions regarding all aspects of information-sharing. Instead, we aim to create ISC as a SCM metaphor: a set of concepts, methods, theories, and technologies that can help to organize concepts, unify existing methods, and discover new solutions that have been neglected. Sharing information requires clear understanding about what to share, whom to share with, how to share, and when to share. The information supply chain framework explicitly captures these questions as information requirements, so we expect that the systems developed under the framework will enable the right *information* to be delivered to the right *recipients* in the right *way* and at the right *time*.

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