From Supply Chains to Demand Networks

Agents in Retailing: The Electrical Bazaar.

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Abstract. A paradigm shift is taking place in logistics. The focus is changing from operational effectiveness to adaptation. Supply Chains will develop into networks that will adapt to consumer demand in almost real time. Time to market, capacity of adaptation and enrichment of customer experience seem to be the key elements of this new paradigm. In this environment emerging technologies like RFID (Radio Frequency ID), Intelligent Products and the Internet, are triggering a reconsideration of methods, procedures and goals.

We present a Multiagent System framework specialized in retail that addresses these changes with the use of rational agents and takes advantages of the new market opportunities. Like in an old bazaar, agents able to learn, cooperate, take advantage of gossip and distinguish between collaborators and competitors, have the ability to adapt, learn and react to a changing environment better than any other structure.

Keywords: Supply Chains, Distributed Artificial Intelligence, Multiagent System.

1. Introduction.

Companies spend between 12%-15% of their revenues in supply chain related activities [1]. The intense competition and enhancements in operational efficiency of the last decade led to a situation where rising profits is increasingly more difficult. Much of the attention shifted to lower cost, taking advantage of the multiplicative effect of cost reduction in operations. At the same time, the amount of goods in developed countries clearly surpasses their needs and retailers turned their heads to product differentiation, fast product turnaround and enrichment of the customer experience as a way to survive in an increasingly crowded market.

The emergence of new technologies (like RF ID - discussed later) and the explosion in connectivity derived from the Internet phenomena are acting as catalyzers of a new conception in logistics where the capacity to adapt to what is being sold is fast replacing operational effectiveness as the key factor. From supply chains where product is pushed to the retailer we are rapidly evolving to demand networks where the whole chain adapts and produces what is being sold at a tremendously fast pace. That paradigm shift will render obsolete the actual methods, mostly based in demand prediction and optimization. Is in this environment where agents seem to be the best alternative [2] because of their capacity to learn, adapt, collaborate and take advantage of local knowledge.

In this paper we will propose a framework for supply chain management specialized in the retail industry. It is based on groups of autonomous agents committed to learn and adapt to the particularities of each environment, but at the same time are able to take advantage of the global knowledge in the system and willing to try and investigate new possibilities and take benefit from existing opportunities.

The main aspects of the framework are: (1) the introduction of rationality in the agents – the agents will try to learn the causes and infer plans of action from them, (2) an integral view to the problem that considerably defers from the actual structure – there will not be a separation between setting the price or making promotions and placing orders through the chain, (3) taking advantage of the new technologies – RFID – and new management tendencies – VMI, (4) the use of an institution as a general framework where the action takes place.

Oddly enough, similarities with the old bazaar are numerous: bidding, gossip, local knowledge, learning, adaptability, customer experience enrichment, just to mention a few. Malls resemble more and more this concept. A representation of this concept for supply chain management is at the heart of our proposal.

Like bazaar shop owners, agents will own part of the shelf and will try to get the most out of it, adapting to demand, advertising promotions and interacting with other agents in an effort of maximizing the profits of their small shop: their part of the shelf.

In section 2 – Supply Chains - we will provide a brief description of the concept and an overview of the software in use, getting a perspective of which are the actual concerns and tendencies. In section 3 we will review the bullwhip effect, the proposed remedies and how the industry is solving the problem also some real cases of innovation in the industry will be presented. Section 4 will be devoted to emerging technologies: RF-ID, Intelligent products and the use of web-services and their impact in the field. Section 5 will complete the state of the art with a review of the proposals from the AI community. In section 6 we will describe the main lines of our proposal and depict in what it defers from the existing ones and why we think it is a better model for retail. In section 7 we will describe our proposal in depth. After we will conclude and introduce some lines of future work.

2. Supply Chains

In the early 1990s, the phrase "supply chain management (SCM)" came into use. The original motive behind the SCM concept was the "elimination of barriers between trading partners" in order to facilitate synchronization of information between them. Behind that, were the waves created by Just in Time – JIT en the 70's.

A common definition of Supply Chain Management is [3] "a connected series of activities concerned with planning, coordinating and controlling materials, parts and finished goods from supplier to customer. It is concerned with two distinct flows (material and information) through the organization". More recently, Fisher [4] distinguishes two overreaching functions in the Supply Chain: "The first is the physical function, which involves converting raw materials into parts and finished goods. The second is market mediation, which involves ensuring that the variety of products should match what people want to buy". A comprehensive review of Supply Chain literature is provided by Tayur [5]. Figure 1 show the structure of a typical Supply Chain, beginning with the supplier and ending with the customer.

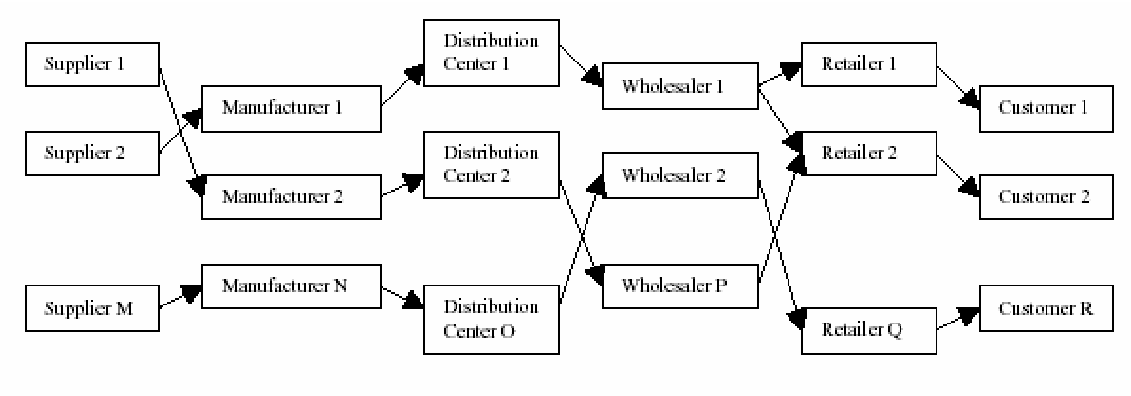

Fig. 1 – A simple Supply Chain.

Traditionally, planning, purchasing, manufacturing, distribution, and marketing operated independently along the supply chain. Each activity had its own set of objectives and often, these objectives were conflicting (for example – manufacturing operations may be designed to maximize throughput and minimize costs, with little consideration for inventory levels, distribution capabilities or market demand). Supply chain management has evolved as a strategy to coordinate activities of these independent functions, and create a single, integrated plan for the entire organization.

The objective of supply chain management activities is to meet customer demand for guaranteed delivery of products with a certain quality, cost and with minimal lead-time. The attempt is to improve responsiveness, understand consumer demand, intelligently control the manufacturing process, and align together the objectives of all partners in the chain. To achieve this objective, companies need to have visibility into the entire supply chain – of its own plans as well as those of its suppliers and customers. Also, the company should be flexible enough that it can adjust, rebuild and re-optimize plans in real time, to take care of unexpected events. These objectives together with an increasingly competitive marketplace and the continuous competition among software vendors led to a further development and confluence of MRP II (Materials Requirements Planning) and ERP (Enterprise Resource Planning) systems, beginning with Advanced Planning and Scheduling tools (APS) to Business Process Optimization (BPO) and later to Collaborative Planning, Forecasting and Replenishment (CPFR).

APS tools try to follow an analytical approach, they are designed to help companies to create plans and schedules that are based on constraints and model demand with the help of sophisticated statistical techniques [6]. Additionally, genetic algorithms [7] and constraint solvers [8] have been used in this type of systems.

BPO (Business Process Optimization) software enlarged the scenario, trying to encompass the whole chain. It gets the data from ERP or legacy systems and tries to find a plan for an optimal scenario based on a view of the company and its trading partners as a whole, leveraging that way the existing investment in software and systems. A company that produces this type of software is i2 Technologies [9], addressing demand fulfilment and demand – supply planning.

CPFR takes an integrated approach to supply chain management among a network of trading partners. The idea behind is to share data and forecasts resulting from it, gaining visibility through the whole supply chain. Worth to mention is the effort of the VICS (Voluntary Inter-industry Standards Committee) [10] that provides with guidelines and a CPFR roadmap to supplement the guidelines. Similar to all software systems discussed before, the successful implementation of CPFR is dependent on data available to existing systems at each trading partner, and their ability to communicate with each other.

As we have seen in this overview software and Supply Chain Management systems have evolved from an autonomous conception to one that realizes that only with information visibility through the whole chain optimal results can be achievable, we will reach the same finding from an analytical point of view in section 3. This view has naturally led to the concept of "dynamic trading networks", comprised of groups of independent business units sharing planning and execution infrastructures "to satisfy demand with an immediate, coordinate response" [11].

C. Heinrich, member of the SAP AG executive board in a presentation to the press on June 13, 2001 said: "The ultimate goal is to create a truly adaptive supply network that can sense and respond to rapidly evolving conditions so that partners can intelligently cooperate to keep demand and supply in close alignment and efficiently coordinate the fulfilment process … We believe that intelligent agents will be key to resolving the increasing challenges companies are faced with in participating and managing global adaptive supply networks."[12]

The above statement reflects the evolution in Logistics and the increasing importance of Agent Technology in the field and the evolution towards new management models where the focus is more on adaptation and customer demand than on operational efficiency. In the "Adaptive Supply Chain Networks" white paper [13] we can read: "Falling margins, globalization, and accelerating innovation cycles are forcing businesses to switch from traditional supply chains to adaptive supply chain networks that possess the flexibility needed to respond to their environment in near real time. During the transition, companies must map the three key process enablers – the management of visibility, velocity, and variability – to the three key information enablers – quality, timeliness, and depth of information. Leveraging technology, including new technologies such as agents and RFID, is crucial to a company's success."

This idea of Adaptive Supply Chain Networks had suffered a further evolution in the academic community around the Auto-ID Center at MIT. They work with the concept of Demand Networks, representing the fact that products will no longer be pushed through the Chain but will be the end point of the Chain, the demand, that will pull for products in a near perfect real time flow of information allowing precise timing in manufacturing and distribution operations. In words of Shomen Data (Director of the Auto-ID Center): "Supply chains and value chains are rapidly evolving toward demand networks. Real-time operational adaptability is essential in fast 'clockspeed' industries. Emerging tools and technologies are poised to converge and catlyze this paradigm shift toward an adaptable business network." [14]

3. The Bullwhip effect – Management tendencies & Real Life Cases.

The Bullwhip effect was first discovered by Procter and Gamble (P&G) examining patterns of demand of Pampers (one of their best-selling products). It consists in the demand amplification effect as it is transmitted thought the supply Chain (Fig.2). The first academic description of the fact is due to Lee [15, 16] as is probably the most cited paper in Supply Chain. But the study of the Dynamics of a multi-echelon supply chain has a long tradition in the field of System Dynamics. The first analysis is due to

Forrester [17, 18], who concludes that a multi-echelon production-distribution system "by virtue of its policies, organization and delays", is "naturally oscillatory".

One of the best descriptions of this effect is the beer game [19], a role playing simulation game first developed at MIT in the 60'. In this game 4 levels in the supply chain are considered: retailer, distributor, wholesaler and manufacturer. Different groups of students play each level. Results in the game fairly resemble the situation in the real world first discovered by P&G.

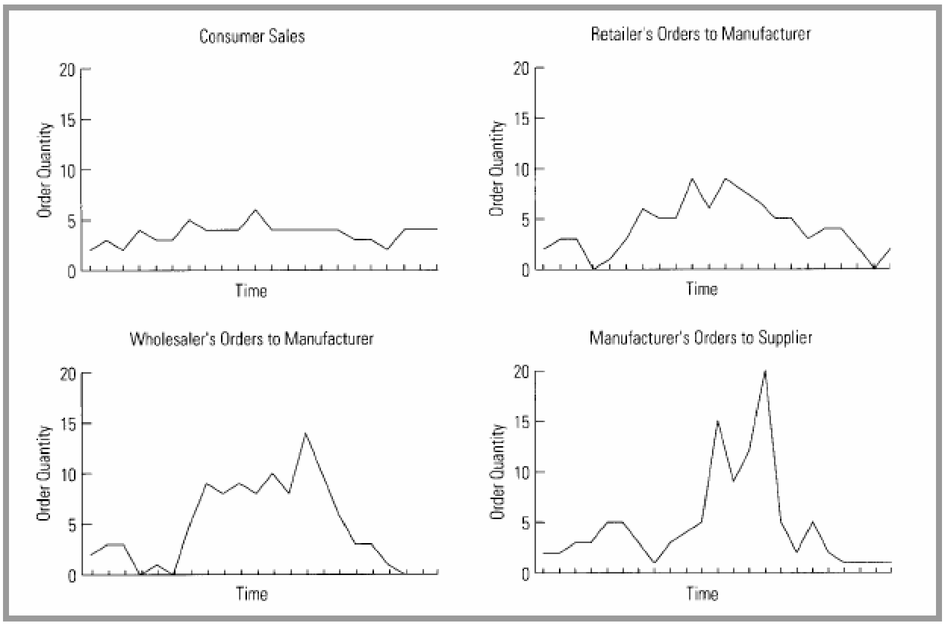

Fig 2. Increasing Variability of orders up in the supply chain.

The beer game or the bullwhip effect has produced a vast amount of literature coming from three different points: the systems dynamic community, the agent-based modeling community and the economics and management science community, a good description and a very fine comparison is due to Scholl [20].

Some simulations of the beer game played by agents exist [21] that suggest that agents can do a better job than humans in demand forecasting and adapting to changing circumstances.

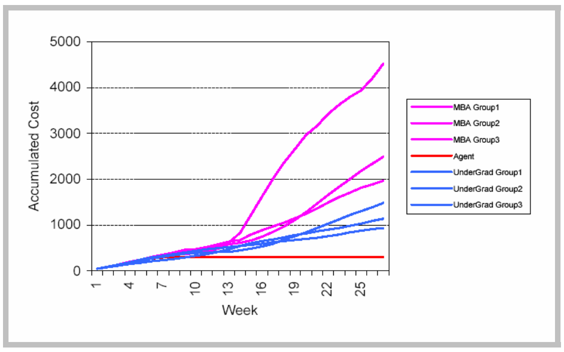

Fig. 3 Agents playing the beer game compared with MBA and underg. students.

In Fig. 3 we can see the performance of several groups of MBA and undergraduate students at MIT compared with genetic agents. As can be seen agents clearly outperform both groups of students. Faced with stochastic demand and stochastic lead time (Fig. 4), experiments also confirm that in simulated environment a Multiagent system can tame the bullwhip effect in supply chains.

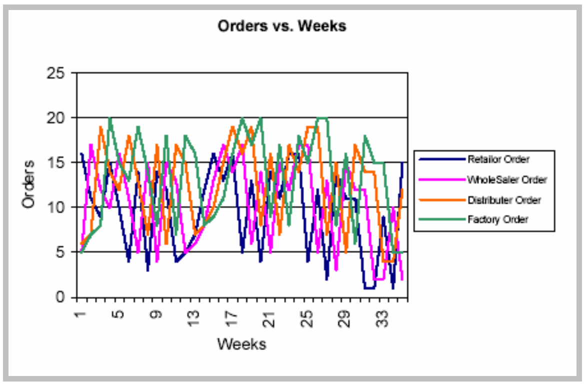

Fig. 4 Agents playing the beer game with stochastic demand and lead time.

Lee et al. [16] see distorted information transmitted through the supply chain as the cause of the bullwhip effect. They think that coordination and planning through the chain can control the effect and propose: (1) information sharing, (2) channel alignment and (3) improved operational efficiency. This is not the only causes proposed in the literature but is certainly widely accepted.

This fact led the business community to find solutions for the bullwhip effect. Basically we can find two groups: ones that collect demand data from their downstream partners (Apple, HP, IBM) and others that take a more radical approach and manage inventories at downstream sites (WallMart and Procter & Gamble), the last approach is called VMI (Vendor Managed Inventory) and is becoming more and more common in retail.

The extraordinary reduction of the time-to-manufacture and time to market has brought JIT practices to the retail sector, examples of that are: the bakery of a supermarket or retailers like Zara with a three weeks inventory turnaround (Inditex)[22]. But at the end of the day logistics is about having the right product in the right place at the right time with the most cost-efficient procedure and this is an exercise of real life and real products. Our quick overview over the state of the art in the subject would not be complete if we did not mention some real life outstanding cases [23].

Federal Express [24] manages 2.5 millions of packages and 400,000 customer service calls daily on average. Today, Federal Express is a leading model of simultaneous processing across an extended supply chain. Maybe the best example of this is its alliance with Proflowers.com (an internet company that runs a portal for delivering fresh flowers), when Proflowers receives an order it is transmitted instantly to Federal Express who send the courier at the same time that generates the shipping label and sends it to the grower. When the pickup occurs the shipping label with all the information is already in the carton of flowers to be shipped. Here we can see how FedEx dealt with the information problem that we mention above, in that case the use of technology allows FedEx to gain information visibility across an extended chain (the grower and Proflowers are not part of FedEx).

Cisco [26] is our last example. Cisco has materialized a "demand driven" production and replenishment process using collaborative distributor/supplier planning/forecasting efforts and online purchasing. By now it receives more than 50% of its orders via the Internet, its customers have 24 hour access to the orders and can validate, configure and price any order/product. Using this customer involvement Cisco reduced orders that required reworking from 15% to 2%. On the other side, Cisco notifies immediately its suppliers when incoming orders deviate from forecasts and integrated suppliers earlier in the ordering process, reducing that way lead times from an average of 40 to 7-21 days and improving revenue by $100 million annually.

In that case is integration and adaptation through the whole chain and not only information sharing the tool being used.

Sun [25] is another example. Sun Peak is a Web-centric network that links 50,000 employees, suppliers and distributors. Sun may encounter 480% spikes in demand for a product from one year to the next, thus is not only a matter of being better at forecasting but at adapting to real time demands on a chain-wide basis, this is the function of Sun Peak make real a vision of a shared extended enterprise-wide data network where collaborative relationships across the chain can take place. Once again we can realize the power of information sharing across the chain.

4. Emerging technologies

There is a group of emerging technologies that concurrently are affecting the field. As every new technology, they enlarge the window of opportunities and possibilities. In that case we have also a high degree of interrelation between them, making these opportunities even larger.

In our discussion we are going to identify four different technologies and discuss their interaction and possible impact in logistics:

- **RFID**. Radio Frequency ID are "smart tags" that replace bar codes, allowing remote product identification. The product transmits its code to receivers on request using radio frequency.
- **Smart labels**. Smart labels are LCD labels that allow changing the price of products instantly.
- **Internet**. Internet provides a "total connected world" allowing information on request from any point.
- **Intelligent products**. Products that can identify themselves describe themselves and can participate in decisions relevant to their own destiny.

Of these four technologies two are core: the RF ID and the Internet. One allows that each product identifies itself in the world and the other can provide endless information about the product and its capabilities. The result of their interaction is the concept of intelligent products. Smart labels (see Figure 5) more than a new technology is a new use of an already existent technology and a proven solution. They are already in use in some retail stores. A good example is Sunka, a Spanish supermarket [27]

Fig. 5 – Smart labels at Sunka.

Smart labels provide the means for changing prices on the fly and react that way to changes in demand or adapt to different conditions. Even they are a simple tool, the fact that price is one of the major variables affecting demand makes them very powerful and a key piece in the platform. Also the increasing tendency to use dynamic pricing policies [28] will probably make their use commonplace.

The importance of the Internet in the new logistics is centred in three key implications:

- As a replacement for Electronic Data Interchange in information exchange between companies. Here Internet is more than a simple protocol replacement because its ubiquity allows that even the smallest shop or vending machine could have at a point access to a global information network.
- As a repository for product information (see section 4.2 about intelligent products for a more detailed discussion). An electronic product code EPC is map to a database containing information about it and its use.
- Allowing total visibility of information through the chain, especially around Work-in-Progress and inventories.

Among all the Internet enabled technologies we cannot forget the importance of web services in the whole schema. Web Services will provide a way for remote disconnected execution of procedures in a global framework, this is basic for the Sarvant structure that will see in the next section or for a truly distributed agent structure like the one we will propose in section 7, and for the replacement of EDI as the dominant technology for information interchange.

4.1 RF ID.

Radio Frequency Id's are small tags (see figure 3 and 4) attached to goods that aim to replace bar codes as a general way for product identification among other applications.

More precisely RF-ID is a generic term for technologies that use radio waves to automatically identify individual items. There are several methods of identifying objects using RFID, but the most common is to store a serial number that identifies a product, and perhaps other information, on a microchip that is attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves returned from the RFID tag into a form that can then be passed on to computers that can make use of it [30].

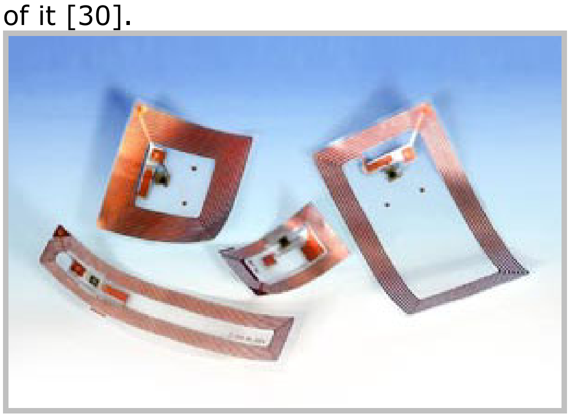

Fig 3. RF ID tags prototypes.

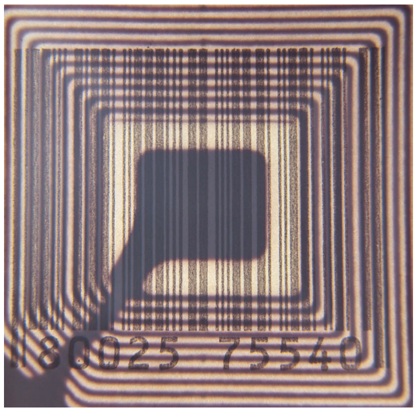

Fig 4. RF ID tag, close view [29].

This code is called EPC (Electronic Product Code), there are currently two standards, one of 96 bits and another of 64. The 96 bits ePC allows 268 million companies to categorize 16 million different products each one where each product can contain over 687 billion individual items, its structure is:

- Header: 8 bits, giving 256 combinations.
- ePC Mgr: 28 bits, giving 268,435,456 combinations.
- Object class: 24 bits, allowing 16,777,216 different combinations.
- Serial number: 36 bits, for a total of 687,194,767,361 combinations.

The 64 bits ePC has the following structure:

- Header: 2 bits, four combinations.
- ePC Mgr: 21 bits, roughly 1 million combinations.
- Object Class: 17 bits.
- Serial Number: 24 bits, for about 16 million combinations.

This "lower" standard will give to each of the 1 million companies that are currently member of UPC/EAN, over 100,000 different products, each product with over 16 million items [31].

RFID tags may be read/write or only read, and depending on if they have an on-board power source or not are active or passive.

- Active tags reduce the power requirements of the reader and can transmit information over relatively far ranges. They possess a battery that can last generally from two to seven years. The downsides of such tags are their cost and their size.

- Passive tags are less complex than active tags, because the reader provides them with their operating power. They are small, light, inexpensive and can last up to 20 years. Their range of transmission is relatively short and RFID systems with passive tags require a much higher-powered set of readers. RFID passive tags are often considered as the next generation bar codes. Their reading does not require a line of sight or contact and can carry more information compared to bar code technology.

	Barcode	**RF ID**
Transmission	Optical	Electromagnetic
Data Volume	100 bytes	128 – 8K bytes
Position for read/write	Visual contact	Non line of sight possible
Reading distance	Centimeters	Meters
Environmental hazards	Dirt	Very small susceptibility

Fig. 6 – Barcode and RF ID technologies comparison.

The system is completed with software acting as a middleware called Savant [32] that manages EPC collisions, queries and information transmission using a distributed architecture model. An Object Name Service (ONS), similar to the Internet DNS, will provide a directory that will link the EPC to the computer where the information about the product is stored. The file will be retrieved by a Savant object and will be forwarded to any application requesting it.

The information about the product will be stored in a PML (Physical Markup Language), based on the widely accepted eXtensible Markup Language format (XML). In addition to product information that does not change (such as material composition), PML will include data that changes constantly (dynamic data) and data that changes over time (temporal data). Dynamic data in a PML file might include the temperature of a shipment of fruit, or vibration levels from a machine. Temporal data changes discretely and intermittently throughout an object's life. One example is an object's location. By making all of this information available in a PML file, companies will be able to use information in new and innovative ways. A company could, for instance, set triggers so the price of a product falls as its date of expiry approaches. Third party logistics providers could offer service-level contracts indicating that goods will be stored at a certain temperature as they are transported. PML files will be stored on a PML server, a dedicated computer that is configured to provide files to other computers requesting them. PML servers will be maintained by manufacturers and will store files for all of the items a manufacturer produces.

Figures 7, 8 and 9 present a pictorial description of how the system is intended to work.

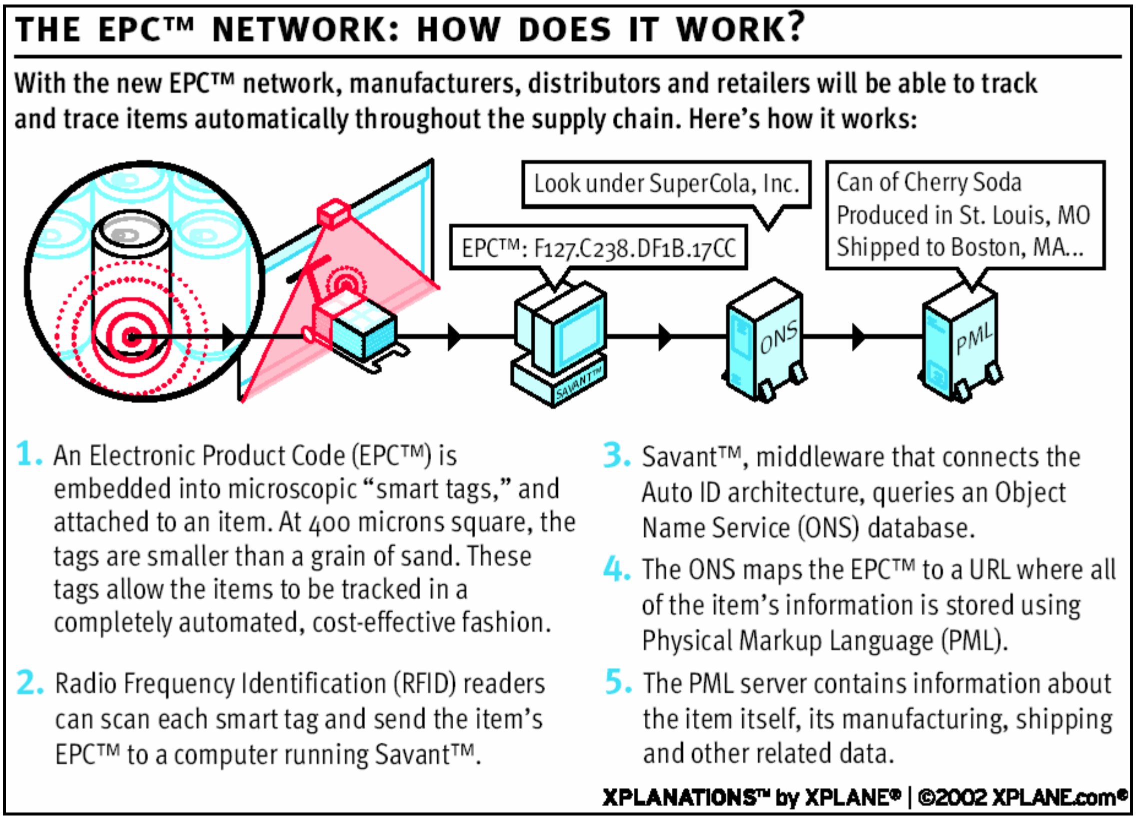

Fig. 7 – Electronic Product Code at work [32].

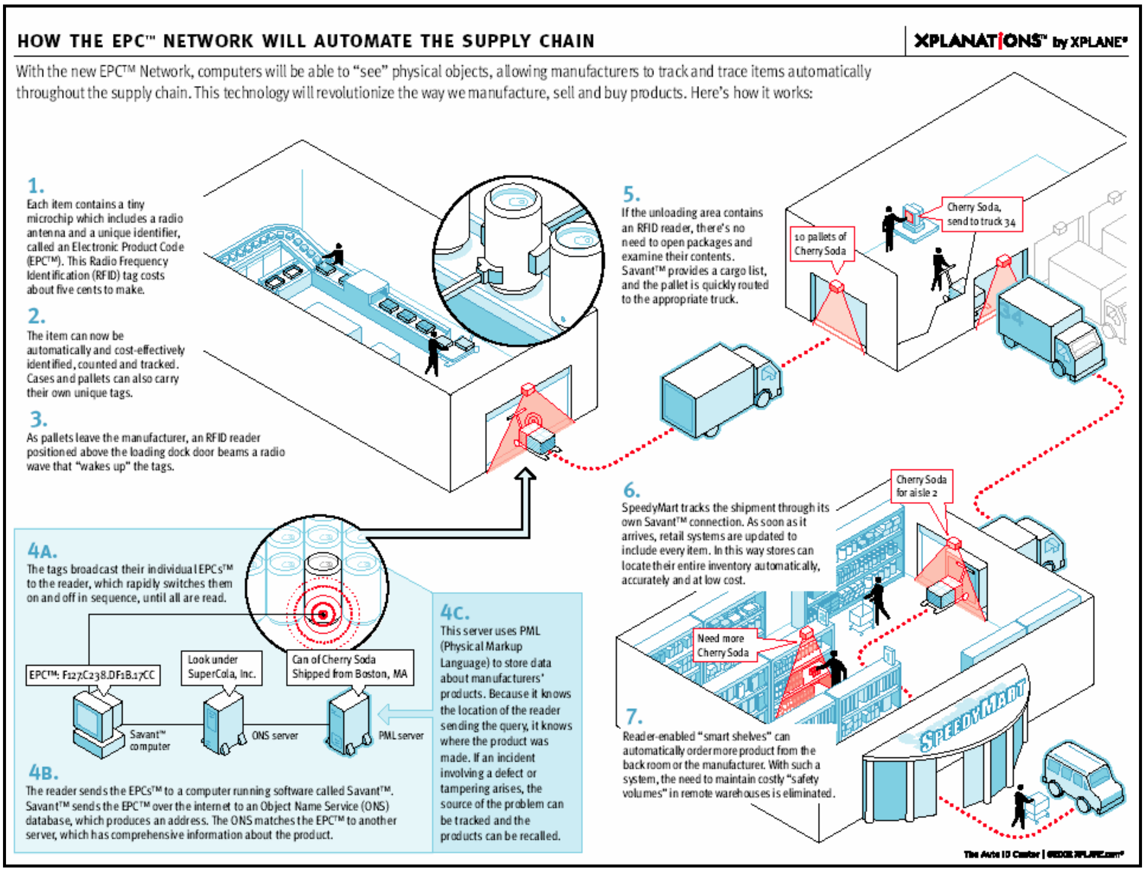

Fig. 8 – EPC Benefits for the Supply Chain [32].

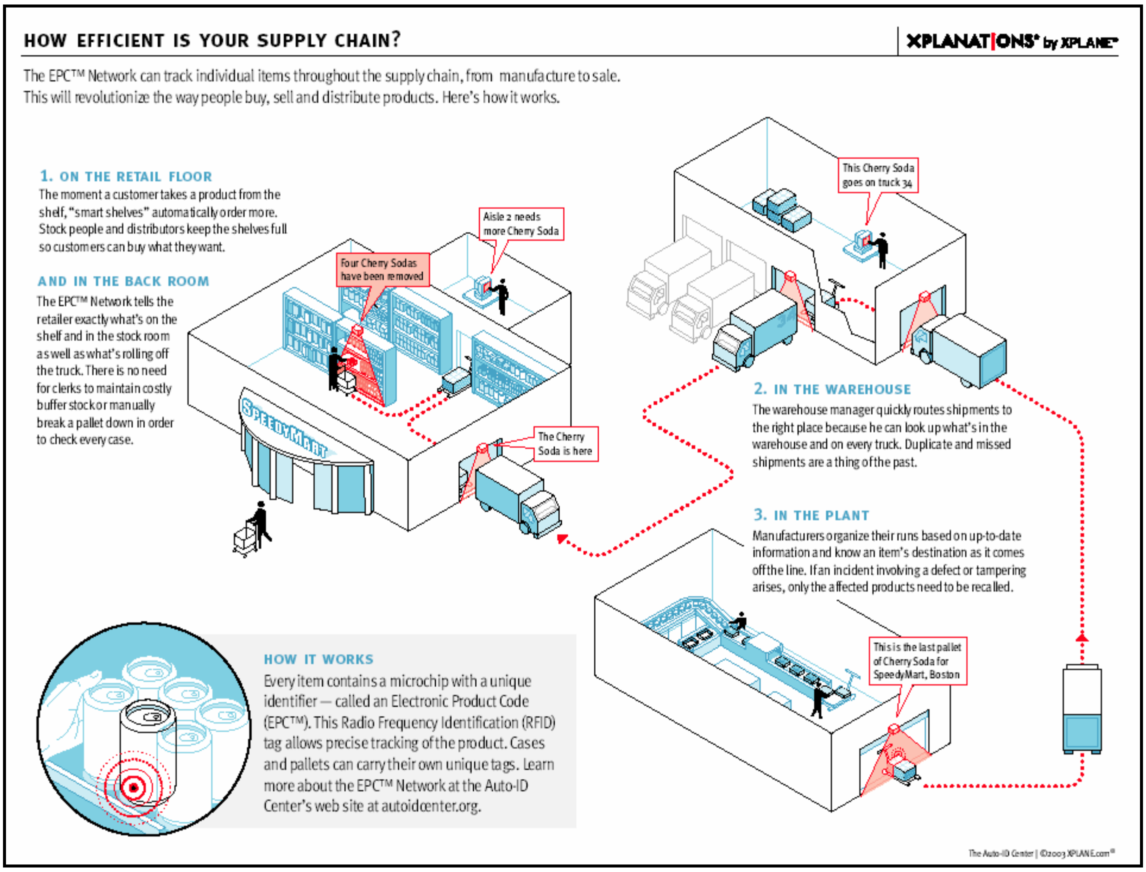

Fig. 9 – EPC Benefits for the Supply Chain [32].

In words of S. Datta, Director of the Auto-ID Center, "By creating an open global network that can identify anything, anywhere, automatically, RFIDs seek to give companies something that, until now, they have only dreamed of: near-perfect supply chain visibility" [33]. One of the first commercial uses of this technology was by Prada [34] in its New York shop located at Soho. RF-ID tags were used not only for stock tracking and checking but to provide extra information to the client about the clothes using plasma screens and streaming videos. In the Prada store's dressing rooms, customers can hang clothes in one lucite box and put accessories, like handbags and belts, in another. An image is captured from their radio-frequency tags and projected on a plasma screen beside the closet in the dressing room. By pushing buttons on the screens, customers can mix and match outfits, and find out more details about the clothing [35].

On May 20, 2003 the German Metro conglomerated opened its first trial store using this technology Intel and German software developer SAP are the principal technology companies behind the Metro pilot project. Hewlett-Packard, Cisco and Philips, among others, are also part of the trial. Among the technological gizmos on display, the store features electronic checkout through radio frequency identification (RFID) tags, "smart shelves" that provide up-to-date information about how much product is left on shelves, self-service information kiosks and the Smart Scale, an IBM invention that can identify the type of produce placed in the pan [36].

In the opinion of the Meta Group, the top 20 retailers will experiment with RFID over the next 18 to 24 months [36].

The most massive deployment of this technology until now has been the last war against Iraq, there every piece of material or equipment that the allies sent to Iraq was track and identified using RF-ID technology, that gave allies a tremendous advantage in speed and capacity of deployment [36a]. Other examples are the Exxon Mobil SpeedPass program which allows for automatic checking in pumps, the recent operation of Gillette buying more than 500 Million tags, Wall Mart demanding that its top 100 suppliers use the technology by 2005 or its use for musical instrument tacking and recovering (http://www.isisid.com). Applications grow each day and RF-ID technology is slowly taking its place in the world either replacing older technologies (bar-codes) or with new uses inventing new functions and markets.

4.2 Intelligent products.

The concept of intelligent product encapsulates a set of capabilities of a commercial product equipped with Auto-Id technology (RF ID) and advanced software that the Auto-ID organization [37] calls software agent. The definition of intelligent product proposed by the Auto-Id Center is one that has all or part of the following five characteristics [38]:

1. Possesses a unique identity.
2. Is capable of communicating effectively with its environment.
3. Can retain or store data about itself.
4. Deploys a language to display its features and production requirements.
5. Is capable of participating in or making decisions relevant to its own destiny.

From there on two levels are distinguished: [39]

- **Level 1** product intelligence, where it is able to communicate its status (location, identity, key features) that covers levels from1 to 3. Expected time frame is from 2 to 5 years.

- **Level 2** product intelligence allows the product to influence its destiny (self routing products, self manufacturing inventory, self preparing,..) and covers from 1 to 5. Expected deployment time frame is 5-10 years.

The intelligent product concept coupled with software agents, opens a new world of possibilities and opportunities. Just to mention a few:

- Automated proof of delivery. The product itself will be the receipt.
- Individual product costing. Product costing could be for the first time individualized automatically.
- Self cooking or self mixing products. Food products can instruct ovens how to cook themselves and for how long.
- Controlled storage. Products can tell refrigerators about their status and temperature can be adjusted accordingly.
- Self tracking products. Products can be mixed in a pallet and have its own destination. This will allow product distribution by third parties in the same way that UPS or FedEx operates.
- High resolution product recall.
- Accurate information for product recycling.
- Elimination of periodical physical stock counts.
- Quality assurance and quality check.
- Dynamic pricing based on product life cycle. Prices can be lower when the product approaches the end of its life cycle.
- Flexible manufacturing. The product can manufacture or assemble itself in the central or a remote location (computers can be customized because they can be identified precisely).
- …

The potential benefits of on-line, out of sight product identification are difficult to asses at this stage of development as it is its impact. But if we only consider the possibilities that can be imagined in the current state of technology, many aspect of the field could change as a result of this development, making not only real concepts like Agile Manufacturing or Demand Networks, but having a clear impact in our everyday lives.

5. Proposals from the AI Community.

The general literature about Supply Chains from the Management Science community is vast. In general they follow the ideas present in the market that we depicted in section two. We found specially interesting the studies of Fisher [4] and Lee [40, 41, 42]. The impact of Internet brought a great deal of controversy and literature about its impact on Supply Chain Management [43]. Recently the discussion shifted to adaptability as we have seen in sections 3 and 4.

In the AI Community we identified three platforms with an important development around and with different focus: ISCM, Mascot and Kasbah. And several focal points of interest about concrete aspects. We will discuss first the platforms and later the specific aspects of the subject.

Kasbah [44], is not specifically a Supply Chain platform but we introduced it here because of the novelty and freshness of its view. Kasbah provides an environment for an add bulletin board where users commission agents to buy and sell goods on their behalf. The prototype presented is quite simple in its agent behaviour but clearly shows the possibilities and raises some interesting questions about how to make the agents smarter and the whole environment more realistic.

The work of Fox and Barbuceanu is probably the most extense, dense and prolific on the subject. It will be impossible to discuss in deep all of it and we have chosen four papers, three that presents the evolution of the ISCM System and one proposal for application in Agile Manufacturing (see section four).

The ISCM (Integrated Supply Chain Management System) was first describe in 1.993 [45]. One of the ideas exposed in this paper is specially important because it will continue to be present in all their work: "we believe that the successful planning and execution of supply chain activities relies upon more sophisticated planning and scheduling algorithms than are available in current MRP systems. We view the planning/scheduling function as the 'conductor' that 'orchestrates' the behaviour of the other supply chain agents. With more sophisticated planning/scheduling algorithms, the overall quality of supply chain management will increase." The system then distinguish between functional (order acquisition, transportation, scheduling, resource management and dispatching) and information agents, the ones who manage the flow of information.

This proposal mimics the actual Supply Chain structure and tries to enhance it by the use more sophisticated tools, as will see in next section our point of departure is the critics of this model and trying to find one that is more suited to the possibilities and the capabilities of an artificial architecture that not necessarily has to copy social structures and limitations of human societies.

A tailored application of the system can be seen in [46], where ISCM has adopted KQML/KIF [6-9] as communication language and is presented as a proposal for an infrastructure for agile manufacturing. This evolves shortly (one year later, 1996) into ABS (Architecture Building Shell) [47]. In [48] we can see its last incarnation, in "Agent-Oriented Supply-Chain Management" the fact that problems cannot be locally contained in subsystems of the chain and the importance of coordination and adaptation is stressed. Also the fact that the "Existing decompositions, as found in MRP (Material Resource Planning) systems, arose out of organizational constraints, legacy systems, and limitation on algorithms" (pp. 166 in [48]). In summary the dynamic, adaptable, reactive, cooperative and reconfigurable aspects are the main focus, separating them from the limitations of traditional architectures that the earlier work presented.

The authors propose to deal with these problems through the use of conversations, mapped in KQML [49] and implemented in COOL [50]. Each conversation plan is mapped to a fully observable, discrete state Markov decision process (MDP) [51, 52]. The representation of the conversation is extended with plans and rules and a RL-like (Reinforcement Learning) treatment is applied to then using the V_n function. The conversations are dynamic and are formed on need or because of an event, allowing dealing with perturbation and cope with change in an effective manner.

There are also two more issues that are important in this framework: the recognisance that agents operate in the context of human organizations where humans must be recognized as privileged members and the fact that the knowledge contained in traditional MRP modules must be open in order to be used by the whole system for answering questions that sometimes will go beyond those originally intended.

Another important centre of work is around Sadeh in the e-Supply Chain Management Laboratory at Carnegie Mellon University. The last result of that work is MASCOT [53]. MASCOT uses a blackboard architecture that borrows from a previous work in the IP3S system (Integrated Process Planning/Production Scheduling) [54] this system was successfully implemented for a Raytheon machine shop. IP3S first and MASCOT later have both an important focus on mixed initiative environments where users interact with the system and explore what if scenarios. MASCOT also uses Micro-Boss [55, 56] a Micro Opportunistic bottleneck scheduling system that works directing scheduling and trying to optimize the bottleneck that is most critical at every point instead of assuming general ones. It was also successfully implemented at a Raytheon machine shop with about 150 work centres.

Another important area of MASCOT that must be taken into account is agent based decision support system, using finite capacity scheduling to coordinate the selection among several courses of action, including the development and evaluation in real time of Available-To-Promise (ATP), Capable-To-Promise (CTP) and Profitable-To-Promise (PTP) functionalities. The e-Supply Chain Laboratory works with the University of Michigan under a joint 5 year NSF/ITR grant in the Maschine project [57].

There are also many areas of interest that are addressed by individual researchers or groups.

Scheduling is one of the main subjects on the field, one interesting paper is from Sauer [58] where besides presenting a hierarchical approach through the whole chain, incorporates feedback from every level and reactive scheduling resulting in teams of cooperative agents that act in a hierarchical and heterarchical way. The framework uses KQML, contract net and a configuration based on components. Other contributions in scheduling can be found in [59] and [60].

Another approach related to scheduling is modelling the Supply Chain as a CSP (Constraint Satisfaction Problem), one of the latest works in this line is from Yung and Yang of Honk Kong University [61], another approach using the Primal decomposition approach (Benders type) is from Zalakota [62] and an older one from Thierry [63].

Wagner and Horling from Honeyell Laboratories and the University of Massachusetts have also a lot of interesting work on the subject. On the basis of TAEMS [64] a simulation framework for task analysis and modelling, a lot of work has been done, most of it in simulation, but also trying to understand better ways to manage the Supply Chain (at a point some versions of TAEMS were implemented in real environments). An interesting contribution in that line is from Wagner and Guralnik [65] they point out the fact that an activity in the chain only has value if the entire chain is performed from start to finish (if the order is cancelled, modified or changed then it has no value or at least a different one). The idea of a global commitment in coordination instead of a peer to peer coordination process is introduced and a new distributed algorithm to implement it is mentioned.

The simulation field is vast and we are not going to explore it, just a mention to the two big entities in the field. The Santa Fe laboratory, agent based [66] and the System Dynamics line at MIT[67].

The Farms laboratory of University of Massachussetts focuses most of its research in the use of agents in manufacturing and design but they have some research in the field, mostly touching economics [68].

Using auctions as a negotiation schema is one of the aspects that has attracted a lot of interest, also literature is abundant, just to mention one line of work of Collins and Gini from the University of Minnesota. They developed MAGNET (Multiagent Negotiation Testbed) [69], an architecture that provides support for complex agent interactions and negotiation protocols.

The contract net protocol [70] and its extension in order to better reflect market conditions and in general mechanism for using auctions is also an active subject, one of its latest contributions is from Menhanjiev as an Agentcities proposal [71].

6. A Multiagent System for Retail.

Our objective in this work is to describe the main lines of a framework for a supply chain in retail. Retail has some unique characteristics that make it different in many aspects to the problems that we have seen until now.

Retail has normally a pattern of repeating purchases with a low involvement, which makes customers more responsive to promotions and more eager to try new products. This also makes the whole chain more centred in what the customer wants and how much they accept a new product. Also relations with suppliers are mostly static (you must carry Coca Cola and Pepsi Cola and probably there will be no alternative products in the short run). Finally, new technologies like Auto-ID and new management approaches like VMI will and are transforming the dynamics of the business and its supply chain to an extent difficult to imagine in other sectors.

There is a paradigm shift taking place in supply chains and especially in retail. Until now the goal was to achieve the maximum efficiency with the minimum inventory, even if this goal remains in place a new emphasis in adaptability is emerging as a key factor.

In words of S. Data, "Supply chains and value chains are rapidly evolving toward demand networks. Real-time operational adaptability is essential in fast 'clockspeed' industries. Emerging tools and technologies are poised to converge and catalyze this paradigm shift toward an adaptable business network."[2].

All proposals that we have seen until now are more directed to a manufacturing supply chain than to the specific problems and opportunities of retail. Also they retain an approach of maintaining the current structure of separation between the marketing and the logistics functions. Also many of the proposals are more concern about specific aspects like scheduling or coordination than to design a model, an architecture that enhances the business.

Also they do not try to integrate the opportunities that new technology is going to put on the table. Like in many fields, technologists (like the Auto-Id center), the Management Science community and the AI community seems more concern following their own path than trying to look over the fence and see what cross opportunities could derive of interaction.

Our proposal tries to provide a fresh look to all these subjects taking a multi-disciplinary approach that could integrate new technologies and provide a framework that is better suited to the problem than the existing ones. Also we see the field as mature enough to think in architectures that do not try to mimic anymore the existing human solutions, but find the best way to approach the situation with agent technology.

We believe that Agents are the best way to solve this problem and than a centralized approach will never be able to grasp the richness of an environment that is plural and where local knowledge is a key factor. Agents as autonomous, intelligent and collaborating entities seem to be the best alternative to bring the answers and to integrate the technologies that this new trends require.

The discrete, dynamic and distributed nature of data and applications require that supply chain solutions not merely respond to requests for information but intelligently anticipate, adapt and actively support users. Agents can support clearly discernible tasks or process, interact with each other in a specified environment (say, inventory management), interact with other Agents directly or via a message bus, continuously harness real-time data (RFID, GPS, sensors, actuators) and share this data with other Agents to offer real-time adaptability in (demand) supply chain (networks)[2].

Let’s now try to discuss what we consider the fundamental points of our proposal and in what it defers from existing solutions:

- **Introduction of rationality in the agents**. As we have seen in some papers in the previous section [53, 58, 65] there is a reconnaissance of the intuition that a supply chain must be considered as a whole and the concept of black boxes that are able to understand a part of the environment without knowing the rest is probably not the best way to go. We propose a model where agents try to understand the causal relations that exist in its world and not only create a system that is able to predict a certain outcome of the future. For example trying to understand beer demand without taking into account the season of the year or weather conditions leads to complicated models that will never succeed in adapt to changing weather conditions in a fast and accurate way.

- **Use of local and global knowledge**. Augmenting the rationality of the agents is the key to our proposal. This knowledge that we have to take advantage of has some characteristics that make it difficult to use: is unstructured, with low levels of certainty and in many cases has the form of insights more than facts. The objective is to infer causal relations and facts from that knowledge. Also it is in many occasions very local in space and time (consider these to examples: the increment of consumption of beer due to a football game in town or the fact that a certain type of immigration is establishing in a certain quarter of the city). We devote a lot of attention to that process because we believe that if adaptation is our objective knowledge is the only way.

- **Managing functions as whole**. The separation of demand planning and marketing functions is artificial and human limitations are probably responsible for it. A clear example of that is when trying to understand demand at the same time that a promotion is rolling on. Clearly the effects of the promotion put a distortion that the process that tries to learn the demand must be aware of if it wants to be effective. Same thing happens to price setting, demand is a function of its price in the market and price swings result in demand changes not because of a change in the function but because of a movement between the function. We propose reunify everything related to the product in an integral product management function as in the product manager schema and instead of relying in existing functions define new ones on the basis of the knowledge that the function uses.

- **Ordering as a bidding process**. It is always difficult to establish priorities among different orders because the ones that know better the importance of the order for them are the ones who place it. Again human structures usually mask that importance pretending that they need is always the most important. We propose a schema where ordering is a bidding process, as any auction it incorporates the importance for the one who place the bid in its price. Also agents that have low product margin or that are in shops where they cannot afford to pay more will tend to use more conservatives strategies in their planning in order to avoid last minute bids. That way the system will be able to auto-regulate.

- **Integration of new technology and new marketing concepts**. Technology like RF-ID will probably change our malls and supermarkets to a place where the enrichment of the customer experience is the objective leaving the administrative process as a thing of the past. RF-ID, agents, web-services,… open the door to a new world of opportunities. Maybe one of the most important is managing real time opportunities that information provides, for example is perfectly feasible to move stock from one shop to the other if conditions require it and that will increase profit or quality of service). Also things like VMI (Vendor Managed Inventory) are here to stay and probably represent the beginning of a process more than any possible ending point.

“It is not the strongest of the species that survive, nor the most intelligent, but the most responsive to change” [72]. In the race from supply chains to demand networks this words of Darwin more than one century old will be more related to the future than we ever imagined. Our proposal goes into that direction: adaptation. In a complex environment like this, the capacity to adapt probably cannot be blind, knowledge is the key to being responsive.

We believe that even a small understanding of the world will provide the system with more clues in how to react than any further progress on more sophisticated planning or scheduling algorithms.

Technologies like Auto-ID will provide the sensors but without intelligence these sensors will be useless. At the end the specie that survived best was not the strongest one, but the one who was able to use its intelligence to better adapt: us.

7. Platform proposal.

Platform proposal - Architecture.

In order to deal effectively with this new environment a Multiagent system is proposed, its main objectives will be:

- Manage the business. Meaning key factors and activities:
    - Stock. Demand forecasting.
    - Price. Finding the best price for the articles on display.
    - Shelf space. Maximizing profit per shelf space.
    - Products. Deciding which products go on display and which don’t.
    - Promotions. Deciding when to put on sale an article and biding for the display of the promotion.
    - Distribution. Finding the best possible distribution procedures from the distribution centers to the stores.

- Solve conflicts. Solve the conflicts that will arise between shops, products or in general the assignment of scare resources in the most profitable way.

- Make use of local intelligence in the global context of the company – society.

- Integrate and make the best possible use of trends and technologies like VMI, JIT, RFID, Electronic LCD labels ...

- Easy to deplete and able to configure itself.

Also the system must comply with several requirements:

- Adaptability. The system must be able to adapt itself to a changing environment and learn from it.

- Intelligence. Each agent will have different and sometimes contradictory goals to fulfill.

- Integration with other agents. Retailer agents must coexist with vendor agents.

- Distributed. The system will always be distributed and must be able to operate in different configurations.

The system will be structured in two basic levels:

- Retailer. That will represent the shop, supermarket, etc… In general the entity with direct contact with customers.

- Distributor. That will represent entities that have local stock of goods and provide service to retailers.

It will be possible to have different distributor levels in a tree or network structure or have the distributor part of the factory. Names describe functions more than places or physical entities.

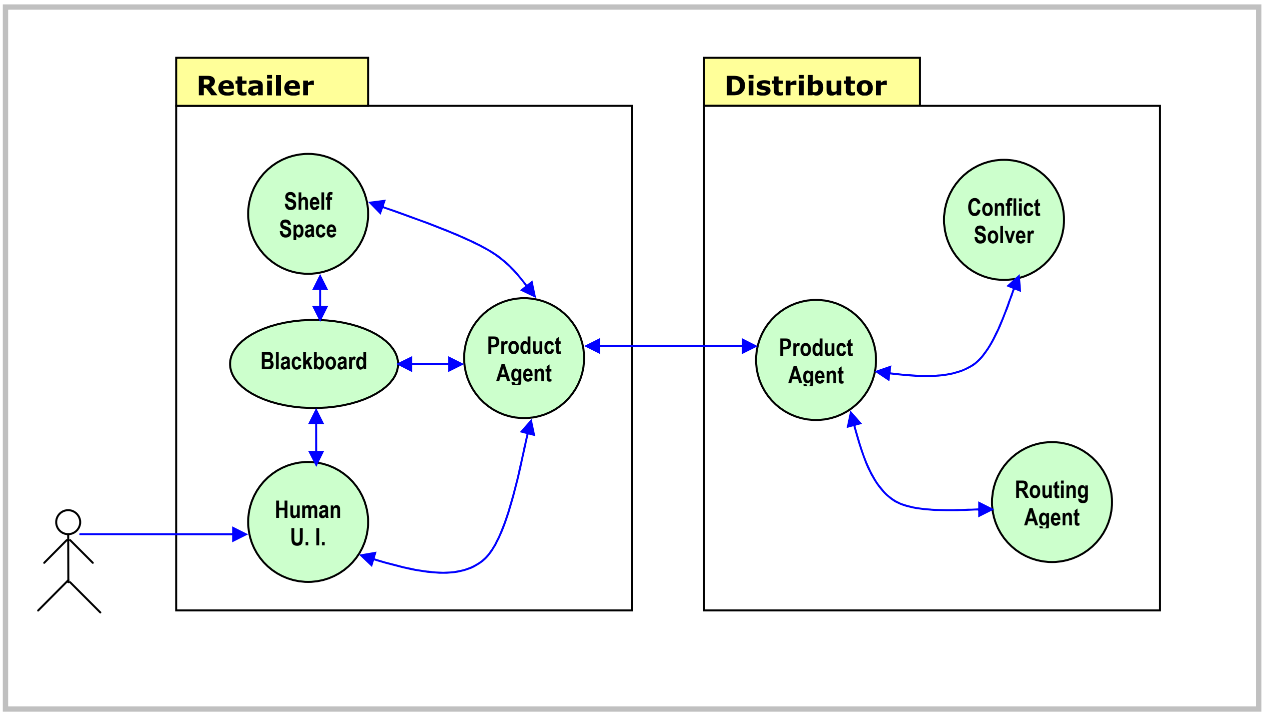

Fig. 10 – A schema of the proposed architecture.

The retailer.

The goals of the agents located in the retailer are probably the more ambitious ones. Because our objective is to build upon the paradigm of demand networks, we are trying to implement a structure where pulling the product is more central than pushing it through the pipe.

The retailer, because its position - with the consumer - at the end of the pipe, is the one who will handle the bulk of the work and the most critical aspects of it.

Perhaps the main question in the retailer structure is how to deal with the products. Several possibilities exist:

- Organize by function. Having one agent that deals with demand, another that deals with price, and so on.

- Organize by brand. Where each brand has a separate agent (that solves the problem of VMI in a very clean way but at the cost of having some agents that have to deal with many types of products – P&G for example- many of them not related to each other).

- Organize by type of product. The concept supporting this organization is the fact that each type of product has a different function and is perceived differently by the customer.

An organization by product seems to be the best, reflecting the idea of the agent as the owner of its shelf space, trying to maximize profits within it.

Our proposal is to have the following structure at the retailer level:

- **Product agent**. Responsible for maximizing the profit of its product line with the assigned shelf space. Its goal is to learn the demand function of the type of products and in particular of each product and maximize profits on that basis. Also product agents are responsible for setting prices and select which products (among the ones in the product line) are going to be carried.

- **Shelf space agent**. Its function is to assign shelf space to product agents trying to maximize profits and service, avoiding out of stock situations. It behaves like a C.S.P. agent.

- **User Interface agent**. Its function is to interact with the user, learning the elements that he cares about. It is a mixture of watchdog and trust agent.

The Distributor.

Agents in the distributor present a structure that is somehow symmetrical to the one we find in the retailer.

We distinguish:

- Product agent. It is symmetrical to the one in the retailer, but in that case its function is to deal with all the agents in retailers and to manage their orders. On the basis of this demand the agent requests an aggregate to the manufacturer. Also product agents advertise themselves and compete to be carried in retailer outlets.

- Conflict solver agent. When there is not enough quantity of one product to serve all requests but some, product agents make a proposal, but it has to be accepted by the conflict resolution agent who takes care that the proposal is good for the company as a whole imposes a fee to the solicitor agent compensating the affected agents. It is an arbitration agent.

- Transport and routing agent. When an order has to be served, this agent is in charge of serving it in the most economical way complying with all the restrictions. Again a C.S.P. agent.

The structure of the distributor can be mounted in a hierarchical way allowing a chain as long as necessary or can be directly located in the manufacturer in the case of a JIT structure (this is the case of Zara, mentioned before).

7.1 Collaboration and Coordination elements.

There is an important need to augment the information that each agent has at its disposal in order to either contextualize it or to increment the number of cases in order to reach a more exact prediction.

Two types of special resources will be used for these purposes: a blackboard system and the use of a qualified form of gossip among agents.

Blackboard.

The blackboard will be the place where external information will be published and where agents can find it. Information like holidays, weather (increase or decrease of temperature), wealth increase, etc….

Also the blackboard will be the repository of a continuous information system with sales per product and shop and more important distances between agents and shops (explained later). This information will be the basis for qualifying any data received from agents because of a particular request or information available in the blackboard.

Product taxonomy

The profile of products and shop are based on the product taxonomy, a hierarchical tree like structure that is used in retailing for identification and cataloguing products. In each node of the taxonomy we identify a product or a group of products as a tuple of

$$T_p = \langle S_p, V_p, M_p, U_p \rangle$$

where T_p represents the element in each node, S_p are the sales of the product (or group of products depending on the level on the taxonomy), V_p stands for the price, M_p for the margin per unit and U_p for the number of units sold. S_p and V_p are normalized from absolute to fractional sales globally or at subclass level on the fly, depending on the needs (if we compare stores we need it globally, if we compare product subclasses of different stores we need it on the product subclass level)

$$S_{pi} = \frac{S_{pi}}{\sum_{i'} S_{pi'}}$$

same thing can be done normalizing products relative to a subclass or the whole taxonomy across stores with different degrees of similarity, giving that way an insight of deviation from the mean.

Each product agent will be responsible for its part of the taxonomy in the blackboard and this part will be interchanged between product agents in order to establish similarities through the use of a distance measure.

Product Affinity

Each product agent will also maintain for every individual product a tuple describing the affinity of that product with respect all other products in the taxonomy

$$\mathrm{Pr} = \langle Su, A \rangle$$
$$Su = \{Su_{p1}, Su_{p2}, \ldots Su_{pn}\} \quad Su_{pi} \in [0..1]$$
$$A = \{A_{p1}, A_{p2}, \ldots A_{pn}\} \quad \mathrm{A}_{pi} \in [-1..1]$$

where Pr stands for each product and Su is a vector with the degree of substitution that each product has respect to this one. A represents the level of affinity between product, describing the degree of complementariness, 0 describes products totally unrelated and 1 completely related (cereal and milk) and -1 indicates a negative correlation (usually substitutes but not necessarily, f.e. expensive champagne and cheap wine are usually negatively correlated – the buyer who loves wine and buys expensive champagne doesn't buy cheap wine). The purpose of Su is to provide a framework for laying out plans to increase customer spending though promotions (substituting low margin products for high margin ones – usually white labels but not necessarily). On the other side the purpose of the affinity measure is to understand the implications of the plans and to evaluate their impact in the whole chain.

The coefficients in the vectors come from the application of a Market Basket Analysis (MBA) to all products and the use of static rules in the Su group (any product can be substituted by products on the same category – especially white labels- and so on).

Same as before this structure will be interchanged though the use of gossip in order to augment the information available for each product.

Electronic gossip.

The implementation of electronic gossip in the system tries to mimic the mechanism that enables humans to get local and global knowledge of the market and keeps them aware of the thinking process that other participants develop.

Through the use of gossip we try to solve one of the biggest problems in marketing, the lack of a meaningful amount of information on what to base assumptions, extrapolations, causal relation understanding, detect trends as earlier as possible, etc. …Thus we will try to augment our own information with the one of peers, qualifying it.

Detecting similarities between branches is the same as trying to classify the community that they serve on the basis of their spending power and consumer habits. Then in that case we only need a subset of the tuple of our taxonomy, taking only into account prices – V_p - and distribution of sales normalized - S_p (in that case prices are not normalized because we need to detect the differences in spending power of the community in order to group similar shops).

We will define Dp (Distance of prices) as the correlation coefficient (the use of the Pearson correlation coefficient was first proposed in the GroupLens project [31]) for prices and Ds (Distance of sales) as the correlation coefficient for sales:

$$Dp_{ij} = \frac{\sum_k (P_{ik} - \overline{P}_i)(P_{jk} - \overline{P}_j)}{\sqrt{\sum_k (P_{ik} - \overline{P}_i)^2 \sum_k (P_{jk} - \overline{P}_j)^2}}$$

where P_{ik} is the price of product k in shop i. Price is probably the more consistent measure because of its capacity of summarizing many qualities of products and represent the utility function of that good for a certain customer.

For sales we will have:

$$Ds_{ij} = \frac{\sum_k (S_{ik} - \overline{S}_i)(S_{jk} - \overline{S}_j)}{\sqrt{\sum_k (S_{ik} - \overline{S}_i)^2 \sum_k (S_{jk} - \overline{S}_j)^2}}$$

where S_{ik} are the normalized sales of product k in shop I, and finally we will define Dsh (Distance of shops) as a weighted average between the Dp and Ds

$$Dsh_{ij} = \alpha \, Dp_{ij} + (1-\alpha) \, Ds_{ij}$$

where α, $0<\alpha<1$ is the relative importance of prices versus sales (a coefficient that can be empirically adjusted).

This will be done at a shop level but also at agent level, giving the similarity between agents. Also this can be done at any group level giving a certain degree of abstraction to the system and making it less susceptible to over-fitting.

In order to make this information available to agents, it will be written in the blackboard. There every agent could see its sales and correlation coefficients with other agents (same thing for the different branches).

Based on that structure an agent has an immediate knowledge of the world just by looking at the blackboard, but can enhance this knowledge asking other agents and has a way to value the relevance of the answers.

One especially interesting feature of this structure is the capacity of augment your own information with the one of peers, qualifying it. This augmented information can be used for demand forecasting, customer positioning or whatever … and can solve one of the big problems at shop level: lack of a meaningful amount of data on what to base for extrapolations or causal relation understanding.

Follows a scene of the institution model designed in Islander [74, 75] (see Figure 10). This scene takes place when the agent detects a variation on the demand of a certain product and tries to find an explanation for it. States W0, W1, W2 and W3 and roles DemandFC, InformationCast and Neighbours constitute the scene. The process is as follows:

1. When a product agent detects a variation in the demand, it looks in the blackboard for any information that could justify the change and updates its list of neighbours based on the information on the blackboard.
2. It establishes itself as InformationCast and asks all the agents in the list that considers necessary information that could justify the change.
3. Every agent who received the request informs the agent with role InformationCast.
4. The agent with the role InformationCast posts the information found in the blackboard and sends it to the neighbours, leaving the role InformationCast.

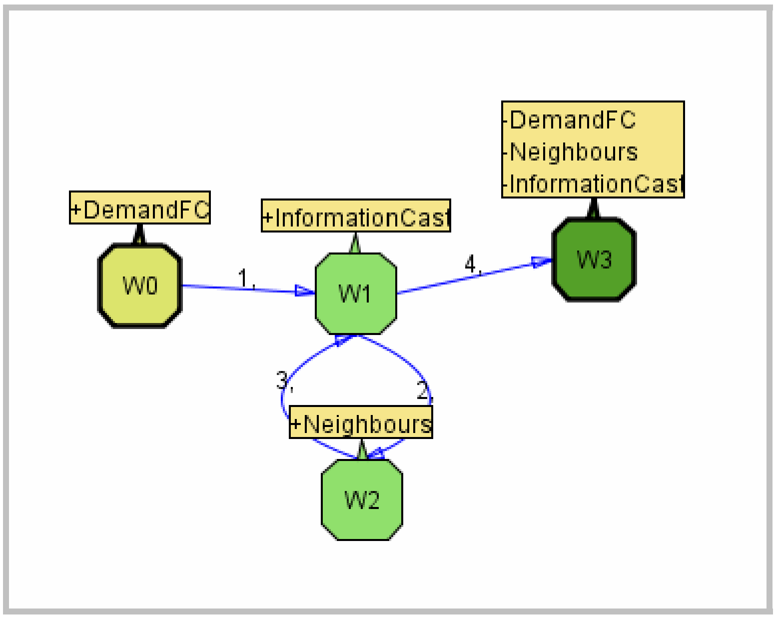

Fig. 10. Model of the scene Demand Variation (Islander).

Distributed Experimentation

Some of the goals of the agents cannot be completed without the use of experimentation, learning the demand function of a product for example can only be done through the use of testing, changing prices, recording the changes in demand and using this information to extrapolate the demand function.

Our agents will use experimentation in order to infer price elasticity and to test promotions before they are rolled out. But gossip and similarity measures will be used in order to be able to carry out the experiments with the less possible impact in the actual business, also this real-time distributed checking will allow a faster reaction and a more precise fine-tuning. Distance measures and communication between agents will also make possible an immediate implementation of what has been learned in almost real time.

A bidding system.

Many of the interactions between agents in the system will include bidding, for example product agents in the retailer will place a bid for product ordering at the distributor.

This bidding process forces agents in the retailer to take the less costly alternative and allows them, at the same time, to pay extra for a service when necessary.

The bidding system automatically makes profits optimum because the one who can pay more (because of its heuristics tell that he can still make a profit with the transaction) gets the goods or the service.

7.2 The Product agent - Retailer.

The goal of the product agent at the retailer is to maximize profits given a certain amount of shelf space.

In order to achieve that goal it must learn the demand function of its line of products on the basis of price and must try to adjust it accordingly maximizing the profits of the different products in the line.

Also, besides this goal, other subgoals, must be achieved:

- Minimize the stock left. In case of products with an expiration date (fresh milk for example).

- Manage JIT inventory. In case of products where inventory is managed that way (bakery or flower shop for example).

- Tolerate a certain amount of over-stock on high margin low use of space products (Gillette razors for example).

As we can see there is a continuum between the aversion to having stock left and the convenience of over-stocking, that continuum depends on the characteristics of the product.

The learning process can be implemented in different ways, from RL (reinforcement learning) to ANN (artificial Neural Networks). The method chosen will depend a lot on the type of product.

More interesting in that case is how to learn price sensitivity. The only possible way is to make different tests on each product in order to get some insight and then use a regression method (standard or hierarchical Bayesian regression are the ones commonly in use) to make a hypothesis about the demand function.

Then in order to maximize profits the agent can:

- Manage shelf space, varying the amount of space assigned to each product (complying with some restrictions: potatoes must be sold …).

- Set prices for every product and change them during the day if convenient (again with some restrictions – if the chain policy is low price prices cannot go higher than a certain limit …).

- Manage promotions per product and changing them during the day (a 50% discount for fresh milk at night maximize profits because is the best alternative is to throw it away).

- Bid for advertisement of its promotions. There will be points of display of promotions in the supermarket (with a small maximum number, like 5 or 6). Agents will bid in order to place their offers in these displays.

- Bid for stock at the Distributor.

Finally the product agent has a mechanism to gain insight about the world and to balance observed increases or decreases of demand within its products with the ones seen in other agents.

This is done in two ways:

- A central blackboard provides newspaper-like information of the world, both local and global (supermarket and company level plus general news).

- The agent can ask other agents and use the answers to assess different situations.

Both mechanisms provide the basis for qualified electronic gossip between agents. This will enable them to distinguish from similar effects but different causes, for example an increase/decrease in sales can be interpreted as: a competing product is stealing market-share, market-share being stole to competitors or a general increase/decrease in sales, etc…

7.3 The Shelf Space Agent Manager - Retailer.

The goal of the shelf space agent manager is to maximize profits complying at the same time with corporate restrictions and policies.

The shelf space agent manager has only one capacity, but a powerful one, to assign and distribute space in the shop to the different agents in charge of product lines.

We can imagine this agent as a planning agent that searches through a space of solutions and tries to find one that is better or at least that the current heuristics evaluates it as possibly better, and complies with the known restrictions.

We have two levels in this process:

- An in-shop level where it accepts bids from all agents that want to increase or decrease its exposure and assigns space accordingly.

- The world or the company in general where it shares its findings with other shops qualified in terms of similarity, allowing the reuse of solutions that worked well in other shops and sharing its own solutions.

Also it makes use of the information in the blackboard referring to particular agreements with companies or general distribution policies (f.e. put milk nearby yogurt).

7.4 Human User Interface Agent - Retailer.

The shop manager must be able to have timely information about what is going on and act upon this information.

Also this agent is in charge of the interface with the company's headquarters. Its goal is to create and maintain trust providing the level of information requested and learning the most valued factors and the appropriate depth at which they have to be communicated.

General policies and instructions are translated to the blackboard by this agent.

Trust learning will be done learning a user profile using inquiries or con-joint analysis techniques and improving the profile with RL (reinforcement) learning.

As all others, this agent will benefit from gossip among peers and augment its information base that way.

7.5 Product agent - Distributor.

The product agent at the distributor is symmetric to the one in the retailer. Its goal is to learn the demand function for the line of products and make the appropriate orders to warehouses or factories.

It receives bids from the different agents in the shops requesting for stock. Arbitrates or serves them and places bids or orders (depending if producers are in the internal or the external network).

Its goal is to maximize profits based on its costs price.

The product agent at the Distributor level carries more products than the ones in display in supermarkets. Then it has also the goal to place the higher margin products in as many shops as it can. In order to accomplish that goal it can advertise promotions or pursue different types of strategies (that are not in conflict with the previous goal).

Also it has to deal with conflicts when an out-of-stock situation occurs. In that case it tries to serve the bids that maximize its profits but it must have the approval of the Conflict Resolution Agent in order to ensure that its solution is not negative to other agents and in that case if approved, a penalty must be paid.

Let's see one of these scenes in Islander.

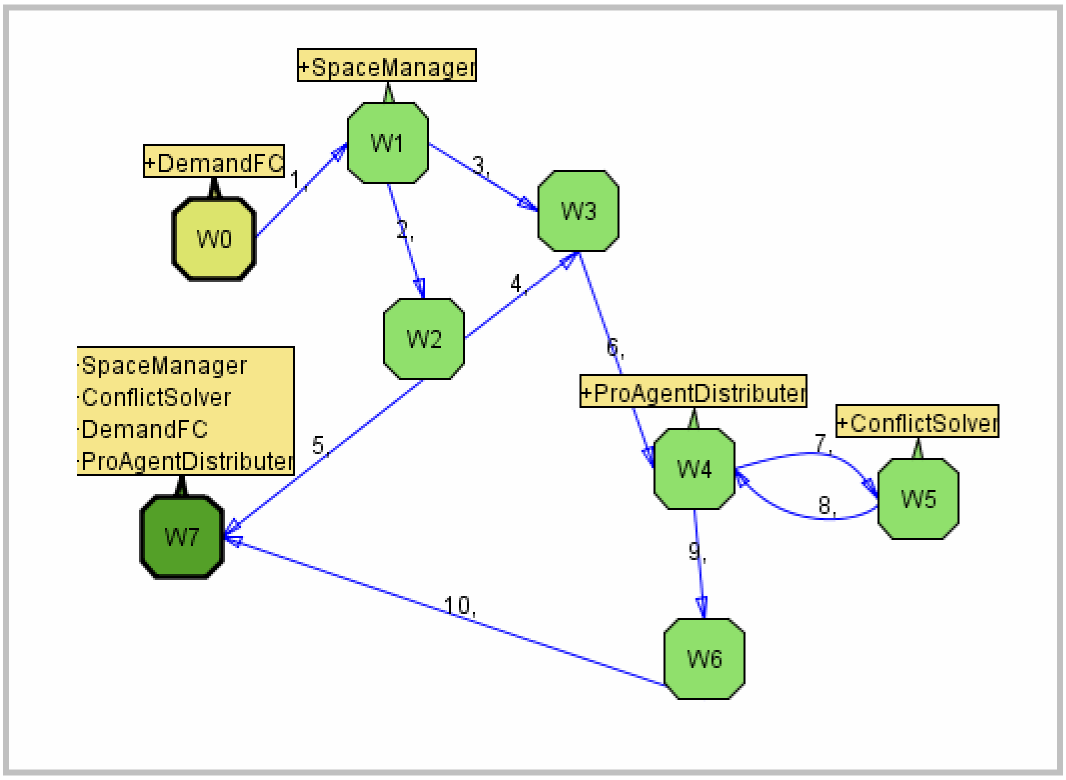

Fig. 11. Model of the scene Product Ordering (Islander).

Figure 11 shows the scene Product Ordering corresponding to the institution model generated with Islander. This scene takes place when a product agent in the retailer decides to place an order on the distributor. The process is as follows,

1. The Product agent asks the SpaceManager agent if it will be any modification on the amount of space assigned to him.
2. If so the Product agent reassigns the order in order to fit whit the available resources (in that reorder the Product agent could decide to choose another product - from the family of products it manages).
3. If the SpaceManager decides to retire the Product agent the process finishes.
4. The Product agent places a bid for product in the Distributor Product agent, the bid indicates the amount that he wants to pay and the maximum reception date.
5. The Product Agent at the Distributor asks the ConflictSolver agent if there is not enough stock to serve all requests.
6. The ConflictSolver returns the penalties that could balance the situation and the Product agent at the distributor passes the information to the Product agent at the retailer.
7. The bidding process starts.
8. A solution is reached or the Product Agent exits.
9. The Product agent at the distributor informs of the solution to the Transport agent and confirms the agreement to the Product agent at the retailer.

7.6 Conflict resolution agent - Distributor.

The conflict resolution agent has the function to arbitrate in case of conflicts due to out-of-stock situations.

It receives a proposal from the product agent at the distributor and its function is to authorize it, to deny it or to authorize it with a fee – a compensation that will be given to other product agents that could loose some business due to the resolution (complementary products).

It takes the information of complementary - substitutive products from the blackboard and its goal is to learn the damage function and to find out the best arbitration rule.

7.7 Routing agent - Distributor.

The routing agent will be the one responsible for putting together the orders of the other agents and elaborating a route that complies with the time requirements of the agents at the shops at the minimum cost.

The routing agent will also need to schedule the planning for complying with the JIT request of the articles managed that way.

One interesting feature of the routing agent could be the redistribution of stock among shops whatever possible. Reducing that way the unneeded stock of a shop and serving another one with a high peak in demand, this feature will be specially interesting in high margin – low consume items and will take advantage of the real time information capability that RF Id can offer.

8. Conclusion and further work.

The first characteristic that shows up after approaching the field is its complexity in terms of interactions and nonlinearity of the events in the system.

Much of this complexity is related to the uncertainty inherent in this type of systems. Uncertainty about the behaviour of consumers, uncertainty about the number and degree of delays caused by external circumstances (mainly transport and out of stock items) and uncertainty about the exact state of the system at a given point.

New technologies like RF-ID work in the direction of reducing some of these uncertainties, the state of the system, in terms of exact stock in that case.

A system of agents is certainly more able to cope with all these uncertainties and work out a better solution because is inherently more able to engage in a continuous process of learning and adaptation.

The system suggests as many questions as it answers providing many interesting lines of research and further work. Among them:

- Qualified augmented information through the use of distance measures.
- Distance measures for electronic gossip and augmenting information.
- Electronic gossip, how agents can acquire and take advantage of informal knowledge.
- Dynamic (on-the-fly) routing reconfiguration to allow last minute stock transfer between shops.
- Developing and maintaining trust between agents and users in complex systems (where the amount of information easily surpasses the assimilation capacity or time availability of the user).
- Demand function learning and price setting through the use of distributed experimentation and distance measures.
- Shelf space management based on constraints and demand estimates.
- Use of informal knowledge in demand estimates.
- Use of early product adoption rate for demand forecasting.

and of course a partial implementation of the system either real or modelled.

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