USING MULTI-AGENT SYSTEMS FOR SECURING PHARMACEUTICAL SUPPLY CHAINS

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ABSTRACT

"Egypt is one of the most countries that face the problem of drug counterfeit, counterfeit trade is near to 1 billion LE, out of 12 billion LE the volume of drug market trade in Egypt"

As announced by the official speaker of the ministry of Health and Population in Egypt. Hence, it can be seen that the drug counterfeit problem is a threatening problem nationally and internationally. Due to the great expansion of supply chains, the drug counterfeit problem has become more complex. In this work, many aspects are discussed including: ePedigree, Databases, RFID, 2D barcodes, Multi-agent systems, and the integration of these tools to develop a system to secure the pharmaceutical supply chain. This paper presents MASP (Multi-Agent System for Pharmaceutical supply chains) and its technological components. The MASP system is developed to control and secure the supply chain and make sure that the product that get out of the manufacturer will find its right way to customers.

Keywords: Drug counterfeit; supply chain; multi-agent systems; ePedigree

1. Introduction

The WHO defines Counterfeit as "A medicine that is deliberately and fraudulently mislabeled with respect to identity and/or source. Counterfeiting can apply to both branded and generic products and counterfeit products may include products with the correct ingredients or with the wrong ingredients, without active ingredients, with insufficient active ingredients or with fake packaging."

This type of illegal behavior leads to (Koh et al. 2003):

1) Compromises of patient safety, 2) Economic loss to established drug manufacturers, 3) A threat to the national security of sovereign countries.

The extent of the problem of counterfeit drugs is unknown. Counterfeiting is difficult to detect, investigate, and quantify. For these reasons, it is hard to know or even estimate the true extent of the problem. What is known is that counterfeit drugs can be found worldwide and are more prevalent in developing countries. The World Health Organization (WHO) estimates that counterfeit drugs range from less than 1% in developed countries to over 30% in some developing countries. According to Tam (2005), root causes of counterfeiting drugs include: The opportunity to make money, with the growing number of expensive drug therapies; the advancement of computer technology. Through the use of computers, it is becoming easier to forge labels and create a packaged product that closely resembles the original; and the growing complexity and size of the supply chain enables forgers to introduce their counterfeit drugs into the supply chain. Critical elements to combat counterfeiting drugs (Who 2005) are: New technologies, stricter licensing requirements, tougher penalties, more secure business practices, increased education, international collaboration and improved reporting systems

To date, no technique has proven effective in eliminating the counterfeit problem. Most detection procedures currently in place rely on manual product inspection by pharmacists or sales representatives to check for evidence of counterfeiting. In the absence of automated inspection

technology, these methods are often too costly to do counterfeit inspection on a broad, periodic basis. If positive detection of counterfeit does occur, it is not clear what action to take because current methods provide incomplete information about the scope of counterfeiting for a particular drug. Product anti-Counterfeit technologies fall into two broad categories; covert or overt (Koh et al. 2003). The covert concept uses security markers or tags on drug coating and the packaging material. Tags are made of food grade materials that can be incorporated into the packaging as adhesive, coating on a label, or in the cap. Tag code is read using a micro-imaging reader and software, it allows authentication at the pill level. The overt concept tries to secure supply chains using visible markers like hologram and color-shifting ink.

Data are the basic building blocks of today's Information Economy and knowledge- based businesses. What's done with data, how they are processed, stored or otherwise manipulated, determines their value. For logistic workers, there are a number of key technology enablers for successful data management: e.g. one- and two-dimensional bar code, wireless data-voice communication, radio frequency identification (RFID), wearable computers and other ergonomic designs.

This work explores how to track and trace data, which originates from reading unique serial number for each product at different locations in a supply chain, can be used to detect suspicious movements of products. The tools required to build a secure supply chain system to combat counterfeiting drugs include Database system, the appropriate method of pedigree tracking (RFID, 2D, other), Hardware and equipment to serve the system, the appropriate software entities to serve the system, and the appropriate contact method between several levels of the supply chain.

The paper is organized as follows; section 2 provides an intensive literature review of the drug counterfeit problem, and the use of auto identification and multi-agent systems to help fighting it. Section 3 discusses ePedigree and RFID tags. Section 4 discusses the structure of the supply chain using multi-agent systems. In section 5, our proposed MASP structure is presented and its working methodology is detailed. Finally, In section 6, MASP's advantages and strengths are shown.

2. Literature overview

Our literature survey is divided into three main aspects, the first is the drug counterfeit problem itself; the second is the role of automatic identification in tracking and tracing; and the third is the multi-agent technology and its use in supply chains generally, and in securing the pharmaceutical supply chain especially.

Regarding the drug counterfeit problem, the FDA provides an annual report of combating drug counterfeit, in its update report of 2005, FDA states the counterfeit problem and the

FDA efforts to fight against drug counterfeiting around the world. WHO (2005) launched discussions on whether an international framework convention or another mechanism of effective international collaboration for combating counterfeit drugs is desirable to address the international dimensions of the problem and to establish normative guidelines on national standards to combat counterfeit drugs. Tiwari (2007) investigated if logistics and supply chain strategy should be aligned with marketing and drug technology strategies to maximize pharmaceutical firm's competitive advantage. Huang et al. (2007) proposed a distributed EPC Information Service (EPC-IS), which makes the ePedigree creation and discovery more robust, scalable, and secure. Finally, Murthy and Robson (2008) used models to evaluate how different parameters such as supply chain layout and available infrastructure influence the costs incurred,

and they provided guidelines for businesses looking to buy or build a traceability system.

Regarding the literature about the role of automatic identification in tracking and tracing, Koh et al. (2003) provided an auto-id based solution that made use of EPC/RFID technology, where EPC stands for Electronic Product Code. Tam (2005) considered the extent of the drug counterfeit problem and how RFID technology can assist in providing greater visibility and security as products move through the pharmaceutical supply chain. Avoine (2005) proposed an adversary model suitable for RFID environments and the access to the communication channels from a set of databases. Staake et al. (2005) proposed a solution for products requiring authentication mechanisms that go beyond track & trace and how the evolving EPC Network should comprehend the functionality to handle tags which support strong cryptography, they suggested extending the upcoming EPC Network infrastructure with an EPC Product Authentication Service. Pearson (2006) proposed requirements for Item-Level Tagging (ILT) deployment and put the foundation for a Tag Data Security Infrastructure (TDSI) for these initiatives. Ayalew et al. (2006) presented the main features of printed graphic identifiers, radio frequency identifiers, and electronic data interchange protocols that have potential for the traceability of food, this can work for medications too. Jung and Cho (2006) presented a novel robust digital audio watermarking scheme to support insertion of dynamically generated user data into the digital content on the side of digital content provider. White et al. (2007) provides a very good comparison between barcoding and RFID Technologies and when it would be more economic to choose between them. Also, Su et al. (2007) presented a comparative basis for the creation of Automatic Identification and Data Capture (AIDC) infrastructure via RFID versus other technologies such as barcode and sensor technologies. Castro and Wamba (2007) took an inside look at the RFID world in order to improve the understanding of this technology, the EPC Network, RFID systems, RFID's potential to improve the efficiency of operations, different areas of application, and a roadmap approach to implementing RFID. In their report, Lehtonen et al. (2007) discusses the BRIDGE project (Building Radio frequency IDentification for the Global Environment), a 13 million Euro RFID project running over 3 years. The objective of the BRIDGE project is to research, develop and implement tools to enable the deployment of EPCglobal applications in Europe; they outlined the findings from the BRIDGE project. The overall goal of this deliverable is to evaluate the business case of anti-counterfeiting applications in order to support affected manufacturers and brand owners in their decision on the application of EPC/RFID technology in the fight against illicit trade. Schmidmayr et al. (2008) discussed the use of 2D barcodes to exchange information between mobile phones and to connect to the mobile web. Kwok et al. (2008) proposed an Intelligent RFID-based Electronic Anti-Counterfeit System (InRECS) that will deliver accurate and global supply chain visibility with intelligent feedback into inventory and materials transfer processes.

Regarding the literature about the multi-agent technology and its use in supply chains, Walsh and Wellman (2000) described some important aspects of supply chain formation, such as hierarchical subtask decomposition, resource contention, decentralization, strategic interactions, and uncertainty, and how MAS can help in modeling such supply chains. Pathak et al. (2000) described the development of an agent-based software system for assisting in decision-making regarding supply chain management and the efficient and effective use of Electronic Data Interchange (EDI) in the automobile industry; they developed

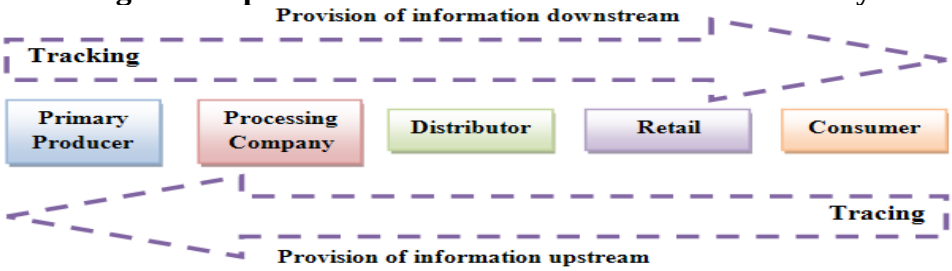
a Model Integrated Computing (MIC)-based supply chain management-modeling environment. Fu and Piplani (2000) proposed a SCM support model as a foundation to combine the supply chain processes with the multi-agent system. Also, a theoretical framework of collaborative inventory management was highlighted to refine and extend the SCM support model with the purpose to synchronize decisions as well as actions. In his book, Wooldridge (2002) gives a very good introduction to multi-agent systems and their protocols and applications. Frey et al. (2003) presented a MAS architecture integrating various intelligent agents systems on the basis of different agent platforms to address the problem of supply chain management. Mitkas et al. (2003) introduced Agent Academy, an integrated development framework that supports, in a single tool, the design of agent behaviors and reusable agent types, the definition of ontologies, and the instantiation of single agents or multi-agent communities. They also implemented a mechanism for embedding rule-based reasoning into them, they called this procedure "agent training" and it is realized by the application of AI techniques for knowledge discovery on application-specific data, which may be available to the agent developer. Davidsson and Wernstedt (2004) created and evaluated sets of intelligent agents that can cooperatively support production and logistics network decisions, as well as to compare their performance to other more traditional methods. Moyaux et al. (2006) presented the fields of supply chain management, multi-agent systems, and the merger of these two fields into multi-agent-based supply chain management, they also discussed the applications of multi-agent Systems in Industrial applications, Commercial applications, Entertainment applications and Medical Applications. Govindu and Chinnam (2007) proposed a generic process-centered methodological framework, Multi-Agent Supply Chain Framework (MASCF), to simplify MAS development for supply chain applications. MASCF introduces the notion of process-centered organization metaphor, and creatively adopts Supply Chain Operations Reference (SCOR) model to a well-structured generic MAS analysis and design methodology, Gaia, for multi-agent supply chain system (MASCS) development. Shirazi and Soroor (2007) presented architecture for strategic information systems, called intelligent agent-based SIS; they introduced some support agents and specified their corresponding roles in an intelligent agent-based SIS architecture. Tweedale et al. (2007) outlines an abridged history of agents as a guide to understand the trends and directions of future agent design. Following the discussion of trends, they looked at the origins of agent technology and its principles. Bellifemine et al. (2008) discussed Java Agent DEvelopment Framework (JADE), a software framework that facilitates development of interoperable intelligent multi-agent systems and that is distributed under an Open Source License, and its technological components together with a discussion of the possible reasons for its success, integrating JADE agents with other technologies and tools. Kovalchuk (2008) developed different algorithms and tested them in the TAC SCM simulated environment; he applied machine learning techniques for forecasting and optimization problems. Lu and Wang (2008) applied a multi-agent approach to study the framework of supply chain in network economy, their proposed multi-agent supply chain framework comprises of four categories of agents; customer-centric, product-centric, supplier-centric and logistic-centric. Turcu et al. (2008) discussed the use of RFID in health including tracking pharmaceuticals from the manufacturer, distributor, and pharmacy to the point of administering medication to the patient. They presented

SIMOPAC health care system that makes use of web services, multi-agent Technologies, RFID technologies. Chen and Tu (2008) proposed a multi-agent system framework called agent-based manufacturing control and coordination (AMCC) system, a agent-based framework using ontology and RFID technology to monitor and control dynamic production flows and also to improve the traceability and visibility of mass customization manufacturing processes, a broad class of agent design and coordination issue regarding just in time (JIT) and just in sequence (JIS) manufacturing processes are also exploited in their study. Trappey et al. (2009) presented a multi-agents system called agent-based collaborative mold production (ACMP) system, it supports the collaborative and autonomous mold manufacturing outsourcing processes, ACMP provides autonomous features to handle major tasks in outsourcing. Their research applied the analytic hierarchy process (AHP) decision models to solve the vendor selection and task selection problems. In addition, radio frequency identification (RFID) technology is adopted to provide a real-time tracking capability for remote collaboration, control and monitoring among outsourcing partners. Sanchez et al. (2009) presented SEMMAS, an ontology-based framework for seamlessly integrating Intelligent Agents and Semantic Web Services. Seilonen et al. (2009) presented a design of a process automation system extended with multi-agent systems (MAS) and experiments with its implementation. They presented an agent platform for process automation as a basis for applying MAS, also, they extended a FIPA-compliant agent platform with process automation specific functionality, this platform utilizes a hierarchical agent organization and a BDI-agent model.

3. Choosing the track and trace tools

First, let's discuss the concepts of tracking and tracing. **Tracking** involves knowing the physical location of a particular drug within the supply chain at all times, while **Tracing** is the ability to know the historical locations, the time spent at each location, record of ownership, packaging configurations and environmental storage conditions for a particular drug (Koh et al. 2003). Track and trace forms the foundation for improved patient safety by giving manufacturers, distributors and pharmacies a systemic method to detect and control counterfeiting, drug diversions and mishandling. Fig.1 illustrates the processes of tracking and tracing.

Fig.1 A simplified view of information flow in traceability



ePedigree refers to an electronic drug pedigree which is a secure electronic record of each distribution of a drug from the sale by a Manufacturer through acquisition and sale by any Wholesale Distributor until final sale to a Pharmacy or other authorized person administering or dispensing the Prescription Drug. It protects the *transaction history* of a given package of drugs.

Radio frequency identification was developed during World War II by the British to distinguish aircraft as being "friend or foe" in the fog of war. To date, RFID, which is also called automatic identification, has only been employed in limited supply management applications, tracking highly valuable or highly secure shipments. However, following the same path as many prior technologies, with its

cost declining, the size of hardware decreasing, and its technological capabilities increasing, all at a rapid rate, RFID is forecasted to replace the ubiquitous barcode technology for item identification over the next decade.

RFID uses a semiconductor (microchip) in a tag or label to store data. Data is transmitted from or written to the tag or label when it is exposed to radio waves of the correct frequency and with the correct communications protocols from an RFID reader. Tags can be either *active* (using a battery to broadcast a locating signal) or *passive* (using power from the RFID reader for location). A firm may use a combination of fixed and hand-held readers for reading RFID tags to gain as complete a picture as has ever been possible of exactly what is in its supply chain and where it is.

The RFID technology, allows manufacturers and distributors to more precisely track drug products through the supply chain. RFID makes it easier to ensure that drugs are authentic, and it also creates an electronic pedigree--a record of the chain of custody from the point of manufacture to the point of dispensing. Electronic pedigrees will improve patient safety and protect the public health by allowing wholesalers and retailers to rapidly identify, quarantine, and report suspected counterfeit drugs and conduct efficient, targeted recalls.

Integrating the RFID and Electronic Product Code (EPC) technologies enables automatic information acquisition and effective information sharing in a supply chain. Now, with RFID tags and readers becoming cheaper and cheaper, it has become possible to implement this technology throughout all phases of the supply chain. As a result, verifying a drug's pedigree can be done in a more confident, faster, and automated way. Large companies such as Pfizer, GlaxoSmithKline, Purdue Pharma, and Gillette have start to use RFID in their products.

Choice of frequency band in supply chain application

- RFID tags use two frequency spectrums: radio and microwave frequencies. These can be further divided into four different types of tags commonly used today: low frequency tags (124 or 134.2 kHz), high frequency tags (13.56 MHz), ultra high frequency tags (868 to 956 MHz) and microwave tags (2.45 GHz).
- Based on technical and deployment characteristics such as read-range, form factor, maturity, global standards, worldwide frequency availability, and reading speed, HF frequency is considered the most efficient range to achieve item-level identification and pedigree tracking while concurrently having the lowest business and technical risk.

Table 1 Comparison of RFID frequencies

Frequency	Regulation	Typical Range	Advantages	Comments
< 135 KHz	ISM Band, High power	< 10 cm (passive)	High liquid Penetration	Access control
13.56 MHz	ISM Band, Nearly identical regulations worldwide	< 1 m (passive)	Medium liquid Penetration	Smart cards, Access control, Vehicle immobilization
433 MHz	ISM Band, Short range communication devices, Non-uniform worldwide	< 100 m (active)	Low liquid Penetration, Works well around metals	Active tags

860.960 MHZ	Non-uniform worldwide	< 10 m (passive US) < 4 m (passive EU)	Best passive communication range	Wal-Mart, DoD mandates
2.45 GHZ	ISM Band, Nearly uniform worldwide	< 3 m (passive) < 50 m (SAW)	Alternative to 900 MHz	Wi-Fi, Bluetooth

4. Structure of the supply chain using multi-agent systems

A supply chain is a network of autonomous entities, or agents, engaged in procurement of raw materials, manufacturing and converting raw materials into finished Products and distribution of finished products.

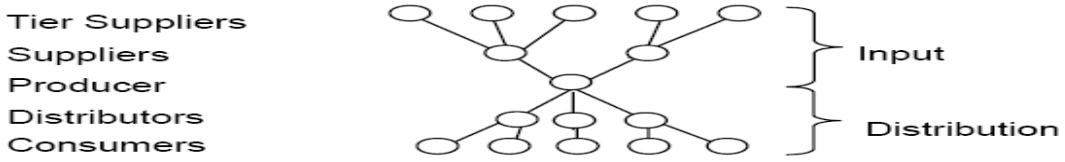


Fig.2 Supply Chain network

Distribution, manufacturing and purchasing organizations along the supply chain often operates independently and have their own objectives, which may be in conflict. The supply chain management (SCM) should ensure the objectives to deliver the right product, at the appropriate time, at the competitive cost, and with customer satisfaction in order to keep the competitive advantages.

The evolution of information technology for supply chain management using MAS

Information is the key to the success of a supply chain because it enables management to make decisions over a broad scope that crosses both functions and companies. The use of the agent/multi-agent system (MAS) paradigm has increased sharply as an important field of research within the Artificial Intelligence area.

An agent is defined by its flexibility, which implies that an agent is:

- ***Reactive***: agents perceive the context in which they operate and react to it appropriately;
- ***Proactive***: an agent has to be able to try and fulfill his own plans or objectives;
- ***Social***: an agent has to be able to communicate with other agents by means of some kind of language.
- ***Autonomy*** (agents have capabilities of task selection, prioritization, goal-directed behavior, decision-making without human intervention);
- ***Persistence*** (code is not executed on demand but runs continuously and decides for itself when it should perform some activity);
- ***Cognition***: agents perform information processing and reasoning, based on their internal knowledge base, in terms of rules;
- ***Communication***: agents participate in communication acts, interacting and sharing knowledge with other agents of the MAS.

Given their properties, the agent technologies seem the most appropriate choice to solve most supply chains problems. This results from the capabilities of the agents to provide solutions in a domain characterized by the distributed nature of data, the complexity of the software solution, the lack of centralized control, the need to ensure the independence of the drug entities, the need to communicate and coordinate in order to

provide specific services to individuals, and the need to receive information and advice proactively. Multi-agent technology could be a favourite alternative to model and simulate the collaboration mechanisms and processes. Therefore, the combination of supply chain process definitions with an advanced infrastructure in terms of multi-agent systems have the potential to make possible a real strategic competitive advantage for the entire supply chain and will enable new forms of business and work. The goal is to create and evaluate sets of intelligent agents that can cooperatively support production and logistics network decisions. Every agent in the SCM support model owns its knowledge, interests, status information, message handlers, process element executors and policies.

5. The MASP System

Our proposed system, MASP (Multi-Agent System for Pharmaceutical supply chains) includes four main agents that are **Packaging** Agent, **Finished Goods** Agent, **Distributor** Agent and **Retailer** Agent. A local database is used in each phase, and is related to the corresponding agent, a central database is used to be accessed by all the agents. Figure 3 illustrates The MASP structure; table 2 illustrates the role of each part in the system.

Table 2 MASP functions

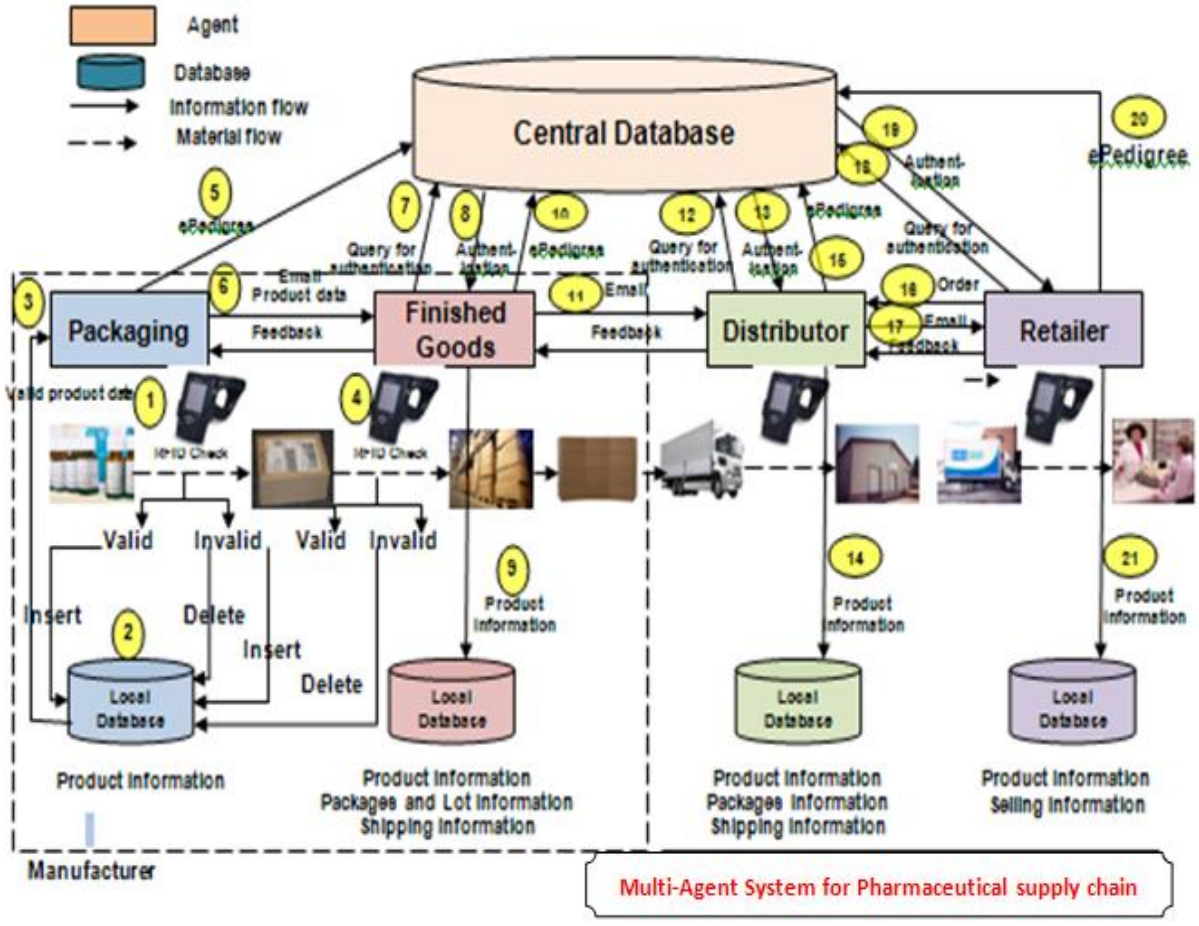


Fig. 3 MASP structure

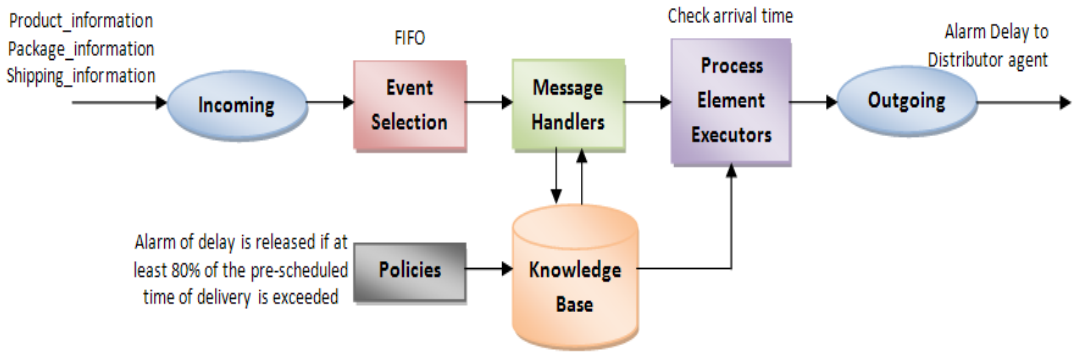
Number	Action
1	Check RFID for products
2	Insert valid products and delete invalid products from local database
3	Inform the agent
4	Check RFID for packages and send data to local database
5	Update the ePedigree at the central database
6	Send an e-mail containing product and package information to FinishedGoods agent
7	Send Query for Authentication to central database
8	Receive Authentication approval from central database
9	Send data of valid products to local database
10	Update the ePedigree at the central database
11	Send an e-mail containing product, package and lot information to Distributor agent
12	Send Query for Authentication to central database
13	Receive Authentication approval from central database
14	Send data of valid products to local database
15	Update the ePedigree at the central database
16	Receive Order from Retailer agent
17	Send an e-mail containing product information to Retailer agent
18	Send Query for Authentication to central database
19	Receive Authentication approval from central database
20	Update the ePedigree at the central database
21	Send data of selling information to local database

6. System Pseudo

Agents operations

We will take the first part of the Pharmacy Retailer agent process as a representative example to see how the agent works. Incoming messages can be dealt with by the agent according to the event selection mechanism that is subject to some pre-determined policies such as first in first out (FIFO). All the messages are based on Knowledge Query and Manipulation Language (KQML) which is a language and protocol for exchanging information and knowledge. Then the selected message is passed to the message handlers to determine how to process the message and which process element executors are to be executed. Meanwhile, the policies, the knowledge and the status information will be applied and retrieved. At the same time, if the outgoing messages are generated, they are sent to the distributor agents. Of course, the local performance of each agent may need to be measured and the policies may be revised according to the new performance information. It should be mentioned that the process element executors, which are derived from the process element framework, are the kernels as the agents are designed to be process-focused. This framework is illustrated if figure 5.

Fig.4 Agent operations



1. Packaging Agent

Verify RFID for product x, for (x=1, x=X)
If Valid
then
Insert product x into **local database**
otherwise
Delete product x from **local database**
Send message (invalid_product) to **ShopFloor agent**
Verify RFID for package y, for (y=1, y=Y)
If Valid
then
Insert package y into **local database**
otherwise
Delete package y from **local database**
Send message (invalid_package_alarm) to **Packaging agent**
Send message (ePedigree) to **central database**
Send message (product_information, package_information) to **FinishedGoods agent**
If Receive message (Alarm_Delay) from **FinishedGoods agent**
then
Send message (Alarm_Delay) to **Packaging agent**
If Receive message (Alarm_Counterfeit) from **FinishedGoods agent**
then
Send message (Alarm_Counterfeit) to **Packaging agent**
Send message (Query_for_Shipping_Information) to **local database**

2. FinishedGoods Agent

Receive message (product information, package information) from **Packaging agent**
Check arrival time t
If ($t \geq 0.8T$)
then
Send message (Alarm_ Delay) to **Packaging agent**
Verify RFID for products X and packages Y
Send message (Query_for_Authentication) to **central database**
Receive message (Authentication) from **central database**
If (true)
then
Insert products and packages into **local database**
otherwise
Delete products and packages from **local database**
Send message (Alarm_Counterfeit) to **Packaging agent**
Send message (ePedigree) to **central database**
Receive message (Order) from **Distributor agent**
Send message (product_information, package_information, lot_information, shipping_information) to **Distributor agent**
If Receive message (Alarm_Delay) from **Distributor agent**
then
Send message (Alarm_Delay) to **FinishedGoods agent**
Locate truck
Contact truck

If Receive message (Alarm_Counterfeit) from **Distributor agent**
then
Send message (Alarm_Counterfeit) to **FinishedGoods agent**
Send message (Query_for_Shipping_Information) to **local database**

3. Distributor Agent

Receive message (product_information, package_information, lot_information, shipping_information) from **FinishedGoods agent**
Check arrival time t
If ($t \geq 0.8T$)
then
Send message (Alarm_ Delay) to **FinishedGoods agent**
Verify RFID for products X, packages Y, lots Z
Send message (Query_for_Authentication) to **central database**
Receive message (Authentication) from **central database**
If (true)
then
Insert products and packages and lots into **local database**
otherwise
Delete products and packages and lots from **local database**
Send message (Alarm_Counterfeit) to **FinishedGoods agent**
Send message (ePedigree) to **central database**
Receive message (Order) from **Retailer agent**
Send message (product_information, package_information, shipping_information) to **Retailer agent**
If Receive message (Alarm_Delay) from **Retailer agent**
then
Send message (Alarm_Delay) to **Distributor agent**
Locate truck
Contact truck
If Receive message (Alarm_Counterfeit) from **Retailer agent**
then
Send message (Alarm_Counterfeit) to **Distributor agent**
Send message (Query_for_Shipping_Information) to **local database**

4. Pharmacy Retailer Agent

Send message (Order) to **Distributor agent**
Receive message (product_information, package_information, shipping_information) from **Distributor agent**
Check arrival time t
If ($t \geq 0.8T$)
then
Send message (Alarm_ Delay) to **Distributor agent**
Verify RFID for products X, packages Y
Send message (Query_for_Authentication) to **central database**
Receive message (Authentication) from **central database**
If (true)
then
Insert products and packages into **local database**
otherwise
Delete products and packages from **local database**
Send message (Alarm_Counterfeit) to **Distributor agent**
Send message (ePedigree) to **central database**
Send message (selling_information) to **local database**

7. Analysis of the used model

The Multi-Agent System for Pharmaceutical supply chain (MASP) approach, developed in this work makes use of the combination of Multi-agent systems, RFID, EPC, Databases and Internet capabilities to provide an effective and efficient system to combat drug counterfeit and provide a reliable ePedigree for drugs. The four agents are linked together, both the Packaging and the Finished Goods agents are at the

manufacturer they start the ePedigree of products and are responsible for the product until it reaches the distributor in time. The Distributor agent ensures that products are received in time and checks their authentication information, also the /distributor agent receives orders from retailers and is responsible for the product until it is delivered to the retailer. The Retailer agent sends orders to the Distributor agent and ensures that products are received in time and checks its authentication. The four agents are connected through the central database which provides the full ePedigree of the products.

Thus, both track and trace, and drug verification are feasible through the implementation of the MASP approach. MASP assumes that all drug manufacturers, carriers, wholesalers and pharmacies have the necessary hardware and computing ability to read and process EPC™ information. It is unrealistic to believe that this capability will occur immediately. However, through recent merger activity, the number of players in the pharmaceutical industry has decreased. This situation could make the job of implementing an industry wide MASP solution to detect and control counterfeit easier because there are fewer major players. The MASP approach would have to be fine-tuned in terms of information synchronization among many different supply chain partners to ensure a high level of reliability for pedigree and drug verification information. If a single supply chain partner did not properly handle information, pedigrees might show gaps that would raise counterfeit questions. The MASP approach assumes different entities within the pharmaceutical supply chain can achieve a common level of cooperation in supporting the information infrastructure. Besides proposed applications in improving track and trace, and drug verification, the MASP approach also serves as the foundation for future applications of importance to the health care industry. The MASP approach is a natural fit to certain classes of dynamic supply chain problems because the paradigm focuses on coordinating the activities of loosely coupled distributed entities, e.g., manufacturers, distribution centers, and retailers (where each of these is represented by an agent). One goal of the paradigm is to enable agents to meet deadlines and resource constraints but also to be flexible, robust, responsive, and adaptive.

8. Conclusions

Supply chain formation is an important problem in the commercial world and can be improved using multi-agent systems. Drug counterfeit is a great problem that is a great challenge for pharmaceutical industry. In this work, it was stated that adoption and wide-spread use of reliable track and trace technology is very potential and provide the required security and authenticity. This would help secure the integrity of the supply chain by providing an accurate drug "pedigree," a record documenting that the drug was manufactured and distributed under secure conditions.

This work is particularly advocated for the implementation of electronic track and traces mechanisms and noted that radio-frequency identification (RFID) is the most promising technology to meet this need. Implementation of RFID will allow supply chain stakeholders to track the chain of custody (or pedigree) of every package of medication. By tying each discrete product unit to a unique electronic serial number, a product can be tracked electronically through every step of the supply chain. Over the last year stakeholders have made tremendous progress in the development and implementation of EPC/RFID. This is a huge endeavor that requires close collaboration among all constituents of the pharmaceutical distribution system. We have observed and supported this collaboration, and we continue to support

it today. The project addresses problems of outmost interest for the whole pharmaceutical supply chain system and introduces novel approaches and technical methods:

- the whole system design follows new conceptual models which resonate with the latest advances in Informational Society; hence the reduction of subjectivism in monitoring processes, a more thorough evaluation of drug flow, and the security against counterfeit;
- the usage of web services and multi-agent technologies for the implementation of complex distributed systems (e.g. functions of communication management);
- as an absolute novelty at the national level, RFID technologies are employed to identify drugs;
- a secure system access ensuring the confidentiality, integrity and security of data;
- the implementation of RFID applications using transponders functioning on different frequencies (125 KHz, 13.56 MHz etc.) and readers observing the ISO15693 standard;
- the suggestion to introduce a EPC to be stored in the electronic identity cards;
- Competitive access to drug records.

Most of these techniques are relatively new, and it can be used to cope with the supply chains strategies in the developed countries.

Our proposed MASP approach has many advantages, first, it provides product and transaction integrity also backwards and forwards accountability is present. MASP is systemic, instance, proactive, dynamic, global, flexible, technology-based, comprehensive, and responsive.

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