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# EPC Network Architecture

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*Abstract*

***EPCglobal [9], a standards management and development body that evolved from the Auto-ID Center [8], has a vision to automate the supply chain. Such automation in the supply chain can be achieved by linking all physical objects globally. To link billions of objects together is a massive task. EPCglobal is developing free and universal standards to regulate the interactions between all of the objects, including object identification, data transfer and data storage. Each object will be uniquely identified with an Electronic Product Code (EPC), linked to one another and the information systems by Radio Frequency Identification (RFID) technology, and the data transfer and data storage are handled by the Electronic Product Code (EPC) Network. This paper focuses on the concepts of the EPC Network and explores the data flow and item tracking applications within the EPC Network. The impact of the EPC Network on the supply chain is investigated. Furthermore, some issues and concerns relating to EPC Network are highlighted.***

## 1. Background Introduction

The EPC Network, originally developed by the Auto-ID Center with its standards now managed by EPCglobal Inc., was designed and implemented to enable all objects in the world to be linked via the Internet. The EPC Network is built upon many fundamental technologies and standards. We review the most important of these technologies and standards in this first section to provide the foundation for understanding the functions, roles, and interactions between the software systems, described in the following sections, that comprise the EPC Network. We explore the data flow within and the item tracking applications using the EPC Network and conclude with an investigation of the impact of the EPC Network on the supply chain.

### A. Radio Frequency Identification

The overall picture of a radio frequency identification (RFID) system is shown in Figure 1. An RFID system consists of 3 major parts, a tag, associated with the object to be identified, a reader, used to extract the object's unique identifier from the tag, and an application system such as the EPC Network. The tags and readers enable the automated identification of tagged objects, and the application system performs the important tasks using this captured information. This paper only focuses on the EPC Network.

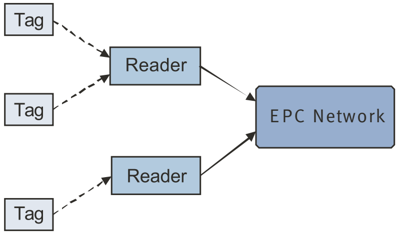


*Fig. 1: The RFID System*

### B. Electronic Product Code

An Electronic Product Code (EPC), is a unique object identifier. A binary representation of the EPC has the following general format:

MSB LSB

| Version Number | Manufacturer | Product | Serial Number |
|---|---|---|---|

The version number specifies the EPC format used by the tag, as there is more than one format of EPC. Currently, there are 64-bit EPC, 96-bit EPC and 256-bit EPC formats. The manufacturer field is a unique number assigned to a particular manufacturer. All the products produced by the same manufacturer will have the same manufacturer number. The product number is a unique number allocated to a specific product class produced by a manufacturer. All products of the same class manufactured by the manufacturer will have the same product number. The serial number is a unique number assigned by the manufacturer to every individual product. No serial number should be duplicated by the manufacturer within a product class. However, different products may reuse the same serial numbers, as the difference in product codes will ensure unique identification of the product. In short, the triplet of manufacturer number, product number, and serial number uniquely identifies an object.

### C. Uniform Resource Identifier

Uniform Resource Identifier (URI) is the generic term for all types of names and addresses that point to any object on the World Wide Web [10]. Both a Uniform Resource Locator (URL) and a Uniform Resource Name (URN) are subsets of a URI. A URL for a Web page commonly starts with “www.”

A URL is an address, pointing to an intended web page. A URN is a specific name used to identify a particular object uniquely. However, it does not specify the location of that particular object. For example: urn:Auto-ID:Adelaide is an URN while http://www.auto-id.org/adelaide is an URL.

### D. Extensible Markup Language

The World Wide Web Consortium (W3C) is an international organisation overseeing the development and evolution of the Internet. It sets the specifications and guidelines for developing web pages, communication and data transfer over the Internet. A common web development language is Hypertext Markup Language (HTML). The function of HTML is to allow a user to define how to display data. Most common web pages are scripted in HTML.

The Extensible Markup Language (XML) [7] is a more generalized markup language. XML enables a user to define their own markup tags that enable the addition of computer comprehensible information to a document. XML focuses on data description. It is up to the user to define the syntax of the markup tags.

## 2. EPC Network

Figure 2 shows the structure of a typical EPC Network. The EPC Network consists of three major components, which are the Savant, the EPC Information Service (EPCIS), and the Object Name Service (ONS). Strictly speaking, the reader should be considered as part of the EPC Network. However, we consider the reader to be a pure RFID tag interrogator under the control of a Savant. Under this view, the reader is not part of the focus of this paper, except to say that implementations of some readers will integrate at least the base functionality of a Savant into the reader itself.

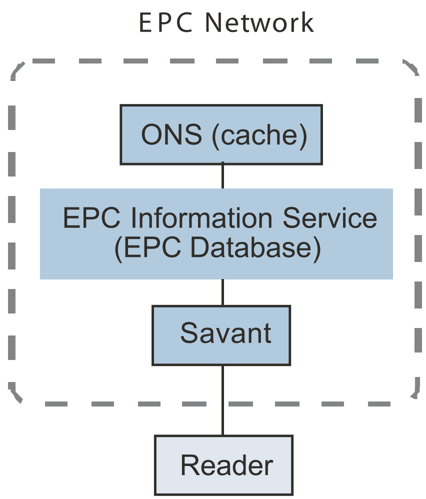


*Fig. 2: EPC Network*

The functionality of each component of an EPC Network will be discussed in detail in later sections. However, it should be noted that the EPC Network shown in Figure 2 is referred to as a local EPC Network. This model is valid for operation within a company or within a private network. Nonetheless, local EPC Networks can be linked together through the Internet so that the global flow of information and data is possible. This is shown in Figure 3.
A global public ONS system may be used also to connect the public portions of the EPC Networks. This global public ONS system connects EPC Networks in a manner similar to how the Domain Name System (DNS) connects computers on the Internet.

The aim and the functionality of the EPC Network can be summarised as below:

- Provide linkage between all physical objects with EPC tags.
- Manage the huge amount of information generated by readers after reading tags.
- Provide a universally used data format in transferring information.

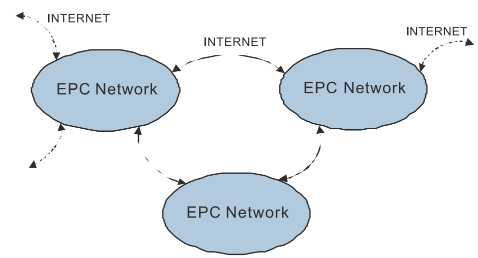


*Fig. 3: Linking all EPC Network through Internet*

## 3. Savant

The Savant is a middleware system located between a reader (or multiple readers) and the applications in RFID systems (Figure 7). Applications operate on top of, or within, the Savant operating environment. The Savant passes requests from the applications to the reader(s) and receives unique tag identifiers and possibly other data from sensors, and passes that information to the applications. The Savant has several fundamental functions integrated into its design, some of which are data filtering, aggregation and counting of tag data. These fundamental functions are required in order to handle the extremely large quantities of data that RFID systems can generate through the continuous interrogation of tags. The Savant consists of two interfaces that allow it to communicate with the outside world. They are the Reader Interface and the Application Interface, where the former provides the connection between the Savant and tag readers, and the latter between the Savant and external applications [2]. A Savant is composed of multiple Savant Services each of which has its own functionality. The Savant Services can be visualized as modules in the Savant. These modules can be combined to perform certain functions for specific applications. Other than Savant Services interacting with each other to perform certain tasks, Savant Services can also interact with external services such as the EPC Information Service (EPCIS) and also the Object Name Service (ONS) [2]. Figure 4 shows the basic architecture of the Savant.

Event Management in Savants is usually their main function. One of the common operations that can be performed is filtering, which is particularly useful in situations where there is heavy data traffic. For example, readers may read data coming in from multiple RFID tags, a number of times. Not all of the data from all of the tags may be of interest to the application. Filtering of that data can eliminate information, that is either redundant (multiple reads of the same data) or that is not needed (tags read but not of interest to that application), from reaching the specific application.

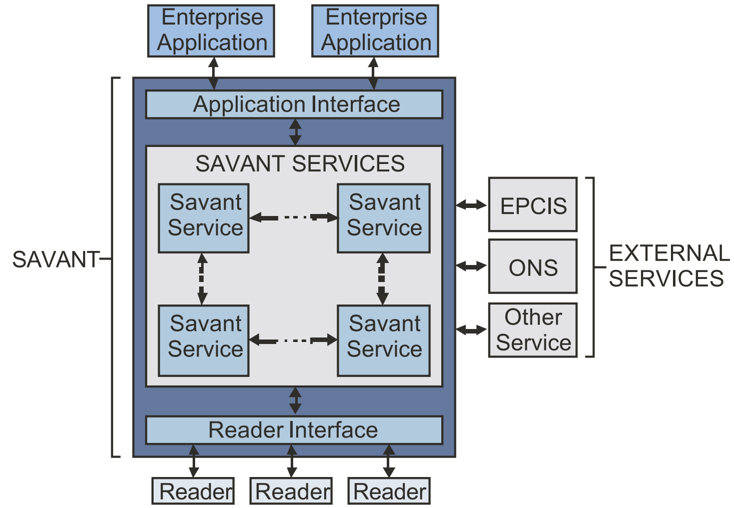


*Fig. 4: Architecture of Savant [2]*

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# 4. Object Name Service

The function of the Object Name Service (ONS) in an EPC Network is to identify the location of the server hosting the appropriate information needed by an application. In other words, the ONS acts like a "reverse phone directory" as the ONS uses a number (EPC number) to retrieve the location (of data) from its database. To encourage rapid development of the ONS, the ONS is purely based on existing Internet technology and infrastructure. The first generation of ONS system designs were based upon DNS systems with the first implementations utilizing existing DNS implementations with customized configurations.

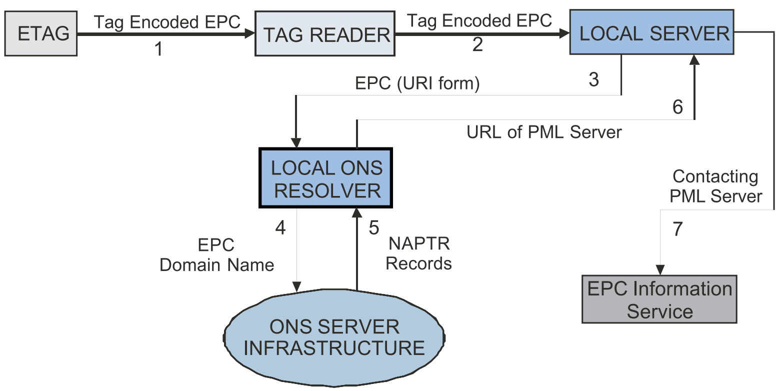


*Figure 5: The Overview of An ONS System [1]*

Figure 5 shows the overview of an ONS system. The explanation of each stage is shown in Table 1.

| | Description | Data Transmitted |
|---|---|---|
| 1 | A reader interrogates an EPC tag and obtains the EPC in binary form. | Binary Code (01 0000000000000000000 10 000000000000011000 000000000000000110010000) |
| 2 | The EPC obtained will be passed to a server | Binary Code (01 0000000000000000000 10 000000000000011000 000000000000000110010000) |
| 3 | The EPC is then converted into URI form (converting binary into integers) | urn:epc:1.2.24.400 |
| 4 | URI is converted into domain name form: | |
| | - remove urn:epc | 1.2.24.400 |
| | - remove serial number of EPC | 1.2.24 |
| | - invert the whole string | 24.2.1 |
| | - append ".onsroot.org" | 24.2.1.onsroot.org |
| 5 | The ONS will generate a set of possible URL. | http://www.example.com/request.php http://www.example.com/service/info_request.asp |
| 6 | The correct URL is picked and extracted. | http://www.example.com/request.php |
| 7 | Server sends a request to the URL. | http://www.example.com/request.php |

*Table 1: Detail Explanation on resolving URL in ONS [1]*

There is a major change to the concept of the ONS since it was first introduced, by the Auto ID Center. The ONS originally would resolve the EPC number into an IP address, such as 127.0.0.1, to find the location of the server that was assumed to be a database, or information server. However, an IP address is only sufficient to locate a server but is not sufficient to locate a particular service. Significant discussion has taken place by members of EPCglobal's Software Action Group. Some have suggested that only one service should reside at a particular IP address and by accessing the server at that IP address, the required service can be requested by the application. Alternatively, taking the model adopted by the World Wide Web, most IP addresses have a general web page that is hosted in a root directory. Other services are hosted either in the same root directory or in sub-directories of the root directory. Under this scenario (multiple services) the ONS will need to resolve down to a unique URL with the exact path and name of the service.

One of the biggest challenges the application faces is on how to pick the correct URL, since a list of URLs corresponding to a particular EPC number may be returned by the ONS server (as shown in step 5 above). The format of the choices returned by ONS is defined in the Naming Authority Pointer (NAPTR). The complete definition of NAPTR can be found in [5]. In essence, NAPTR is a collection of information that points to the right location on the World Wide Web when only an URI is provided. The format is as shown below:

[Order][Pref][Flags][Service][Regexp][Replacement]

The URL is located in the field [Regexp] while [Order], [Pref] (Preference), and [Flags] are used to state the preference order of a list of URLs. [Service] is used to specify the type of service that is offered, such as HTML or PML, while [Replacement] is reserved for future use.

## 5. Physical Mark-Up Language

The Physical Markup Language (PML) defines the way information is transferred in the EPC Network system. Currently, it contains two sets of different vocabularies. If needed, PML can always be expanded to include more sets of vocabularies. The two sets of existing vocabularies are PML Core and Savant Extension as shown in Figure 6.

Savant Extension is used for communication between the Savant and enterprise applications and is not the focus of this document. The PML Core provides the standard and format for the data transferred. PML Core should be understood by all the nodes in the EPC Network, namely, the ONS, the Savant and the EPCIS. This ensures smooth data transfer and easy system set up, since all systems are communicating in a common language.

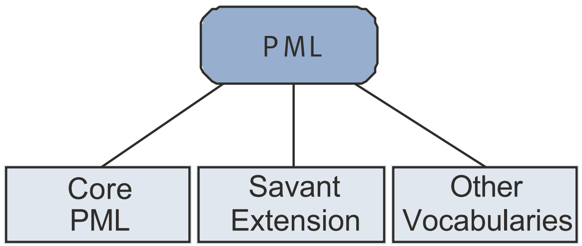


*Fig. 6: The PML Structure [3]*

PML Core is based on the existing standard, XML Schema Language. It uses "tags" to format the data before a data is sent. It has to be noted that the term "tags" here does not refer to RFID tags, but instead it refers to the concept of tags in a programming language, such as <pmlcore:Sensor>. All "tags" have the prefix of "<" and postfix of ">" within a document.

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PML Core is rigid and simple. All the PML Core "tags" can be understood easily. PML does not use short "tags" for data formatting. Although more bandwidth will be required for data transfer, compared to using short "tags", the use of longer descriptive tags increases human readability and hopefully will avoid mistakes in interpreting and understanding the data, and how that data is to be handled.

PML Core only handles Observables, which are the physical entities or attributes of an object. Though this includes some relevant data of an object, for example the expiry date and manufacturing date, PML Core does not interpret the data that it handles.

## 6. EPC Information Service

As mentioned in the previous section, PML is used in communication between all the nodes in an EPC Network. One of the nodes in an EPC Network is called the EPC Information Service (EPCIS), which is the gateway between any requester of information and the database. It receives and sends messages in PML with any requester of information, although it's communication with the database can be in any format or standard.

Existing databases run on different platforms using different programs implemented with different languages. Different commands are used to access or store data in different databases. It would be impractical to have all existing databases communicate in a common language, such as PML. Hence, in the context of EPC Network, the EPCIS is the "interpreter" communicating between database(s) and application(s).

EPCIS generates PML in order to allow local applications to communicate with non-local (outside world) systems through the Simple Object Access Protocol (SOAP) interface. SOAP is a simple protocol based solely on XML to allow applications to exchange data using the Hypertext Transfer Protocol (HTTP). HTTP is used to access Internet web pages. As a consequence, any computer that can access the Internet using HTTP can be connected through SOAP. This is particularly useful when an application wants to establish a data transfer link with another computer, which is protected by a strong firewall.

## 7. Overall Picture of Enterprise System

The main components of an enterprise system are readers, Savants, EPCIS, ONS, and the enterprise applications as shown in Figure 7. A reader identifies a tag (or multiple tags) when a tag or tags enter the interrogating field of the reader. The EPC number of the tag is read by the reader and that EPC number will be forwarded to the Savant. The Savant will then handle the event and if the Savant determines that such information is required by the enterprise application, it will communicate the tag data to the application. The Savant can be configured to send the data directly to the database, or pass the tag data on to the EPCIS. The EPCIS will be able to communicate with the database and store the tag data as required.

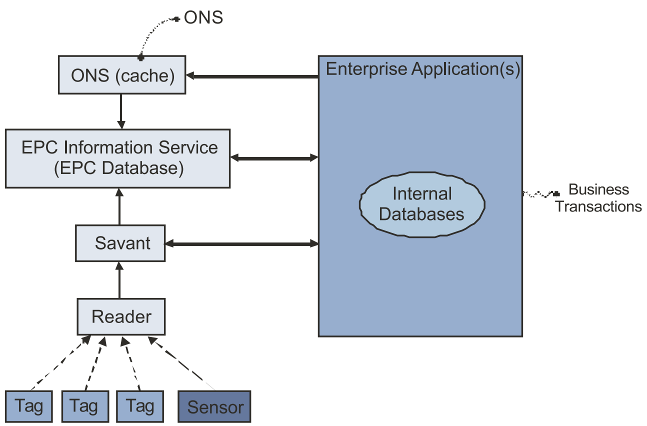


*Fig. 7: Components of EPC Network Architecture [3]*

In the case where the EPC number is unknown to an EPC Network system, the application needing to know more information about that EPC number will consult the ONS to obtain the location of the information corresponding to that particular EPC number. If the local ONS is unable to resolve the EPC number into an URL, the ONS will interrogate other ONS systems higher up the ONS hierarchy, and could eventually make an enquiry at the root ONS global directory via the Internet. The correct URL will then be passed to the EPCIS in order to generate a request in PML format. The request is then sent through the Internet with the URL just retrieved as its destination.

As far as the EPC Network is concerned, there is no specification on the enterprise application. Hence, if any enterprise or company wishes to incorporate EPC Network on top of their existing enterprise application system, they do not need to change the existing application. What is required is a bridging program that links the existing enterprise application and the EPC Network.

There is no need to worry about the compatibility of the existing database too. As mentioned before in the EPCIS section, EPCIS will bridge the database with the rest of the EPC Network. Again, the tweaking of EPCIS to support a particular database system is not as difficult as to change the entire local database.

## 8. A Supply Chain Model

Figure 8 shows an example of a simple supply chain model. There are many parties involved, and these parties are usually separate businesses, each with unique enterprise applications. The central party in this example is the product manufacturer.

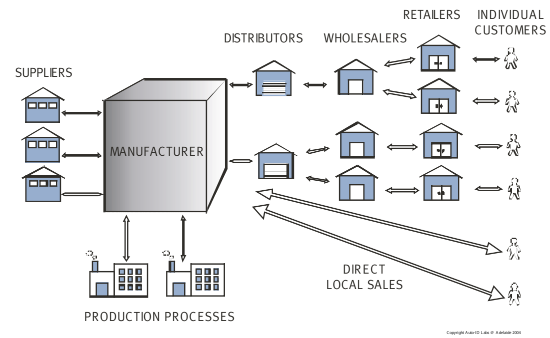


*Fig. 8: Model of Supply Chain*

The manufacturer is linked to raw material suppliers, production factories, distributors and some direct sales customer. The manufacturer produces products and provides those products on to distributors. The distributors will distribute the products to wholesalers and the wholesalers will then pass the products on to retailers, who in turn sell the products to individual customers. In reality, multiple linkages or relationships are present, and the distribution system is much more complex than that shown in Figure 8.

For example, in certain cases, manufacturers may also link directly to wholesalers and even retailers, or single wholesalers that are linked to more than one distributor or even wholesalers linking directly to individual customers. Although there are many more possible outcomes of linkages that may appear in the real world, the simple model that is presented in Figure 8, demonstrates the concepts.

Under the EPC Network concept, each party in this simple model, except for individual customers, should keep an Enterprise System running. In a supply chain that is completely RFID enabled, all transactions except the transactions involving individual customers can be automated. Since the data from RFID systems can now be available in real time, by the use of RFID readers throughout the supply chain, complete visibility of the supply chain is available for the first time. Enterprise applications exploiting knowledge based architectures, could "learn" how to react to various events, and alarm managers when critical events occur. Below are a few scenarios showing how the EPC Network system can bring about improvements to the supply chain:

### A. Efficiency in Inventory Management and Visibility

When a retailer sells a product to a customer, the RFID tag attached to the product will be scanned. The local system of the retailer will be informed of the current status of the product (i.e. product being sold). If the stock of that particular product of the retailer is running low, the local system can automatically send a request to the wholesaler for a stock reorder. The wholesaler, upon receiving the order request from that retailer, will automatically check through ist inventory for stock availability. If the stock level is sufficient, the goods will then be dispatched to the retailer. If the stock level is low, either before or after the goods are dispatched, the wholesaler can place an order to the distributor automatically. A similar process will occur between the manufacturer and the distributor, and of course between the manufacturer and its raw material suppliers. Figure 9 shows the illustration for this scenario.

It has to be noted that the information of the product supplier should be stored in the local system of the product receiver for restocking purposes. This information is cached locally, and could be provided as part of the Advanced Shipping Notice (ASN) provided to the receiver by the supplier. This is because the global public ONS system only point to the manufacturer of a particular product and not the middle parties such as the distributors or wholesalers. Hence, for example, the retailer should have the information of the wholesaler to enable it to place a reorder of a product from the appropriate wholesaler (and similarly, the wholesaler should have the information of the distributor). From the scenario above, it can be seen that this automated system will maintain an optimum stock level while keeping a balance between product availability in the retail store, and minimize the risk of having excess stock being idle in back room storage.

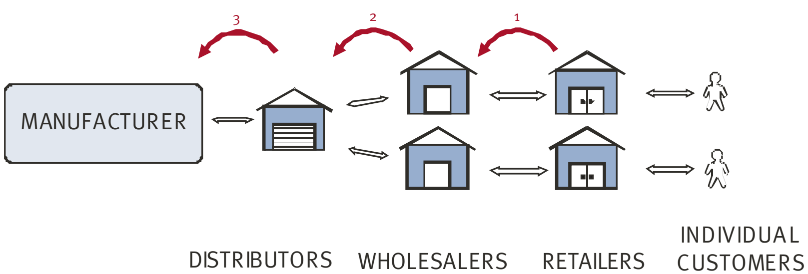


*Fig. 9: Product Re-ordering*

In addition, with the implementation of the EPC Network in the supply chain, goods (or objects) can be easily traced and located along the chain. With this goods visibility, information on restocking period (including the total handling and dispatching time) can be more accurately and conveniently obtained. However, to ensure the privacy of a party, the information of its competitors will not be accessible. For example, a wholesaler will not have the access to the information of the customers (i.e. retailers) of another wholesaler. This is because each unique product, with a unique EPC number must have a unique path through the supply chain.

### B. Anti-Gray-Market and Anti-Counterfeiting

Products falling into gray-markets have been one of the main issues that are of much concern in some industries, such as the pharmaceutical industry. One scenario where gray-market goods appear is in the reimportation of products which were previously exported from one country to another. For local reasons, some of the exported products are sold at cheaper sometimes subsidized prices, in the other country. Some operators illegally import products back to the country of origin, where substantial profits can be made by selling the products at the higher domestic price.

Other than the gray-market issue, product authenticity is also a major issue of concern to users. For example, in the pharmaceutical industry, most high value drugs are illegally manufactured by various manufacturers. Many of these products are the same in potency as the authentic product, but some provide no benefit, or worse, cause harm. Patients must receive the correct drug that matches their prescription, and not a copy with unknown potency. The use of the EPC network can authenticate the unique package, right back to the manufacturer, and enable the retailer and user to differentiate between the original drug and the copy.

Since many products, such as pharmaceutical products, are health and safety related, the issue of gray-market distribution and product authenticity may be addressed by the integration of EPC Network into the pharmaceutical supply chain.

Figure 10 shows one possible data flow in an EPC enterprise system to fight gray-market distribution. When a product is sold and the EPC is detected in the check out point, the local system will send a request to the manufacturer to check the validity of that particular item. The manufacturer, upon receiving the request, will make an enquiry to its distributors. The distributor, with the record of that product, will make an enquiry to its wholesalers. The same situation repeats between wholesaler and retailer. If valid supply path exists for that product, the product is validated. Gray-market goods would not pass this examination and an alert can be sent to the appropriate authority when gray-market goods are sold.

For product authentication, a party such as the retailer will only need to send the request to the manufacturer. The manufacturer will check the EPC received with its database. If the item exists and the EPC matches the records in the database (including no multiple sale records), the item can be validated and proved authentic.

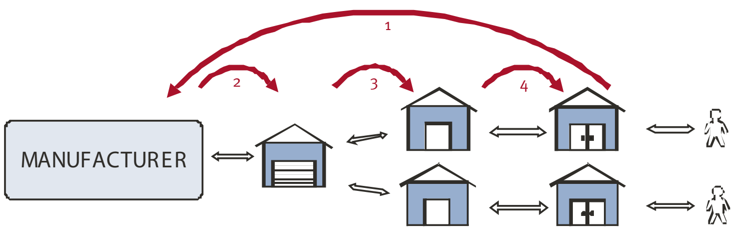


*Fig. 10: Anti-counterfeiting Solution*

### C. Other improvements

Apart from the obvious advantages of supply chain visibility and the reduction in labour needed to check and scan shipments, to confirm that the correct goods were received, there are many other advantages of implementing the EPC Network in the supply chain. These include amongst many others, the easy and efficient recall of products, back to their manufacturers whenever any unforeseen production problem occurs during the manufacturing process, or in the supply chain, and the convenient identification of returned or rejected goods, at all levels of the supply chain, from retailer back to manufacturer.

## 9. Some Issues and Concern

### A. Savant and Savant Communication

When "Savant and Savant Communication" is mentioned, many people will think of the communication between two equivalent Savants. This is a misconception of the Savant system.

The communication between Savants only happens between Savants of different level, such as the communication of a basic Savant with a higher level Savant, in the hierarchical structure of Savants. For example, if a basic Savant cannot handle the data filtering, it will send the data to a higher level Savant for filtering.

There is still no documentation or specification on the communication between two equivalent Savants, and the practicability of the communication between two Savants of equal functionality level is still not clear.

### B. Dynamic Savant Services Update

There are views that users should be allowed to upload services (i.e. Java classes) onto any Savant system. For example, if a buyer of a particular cold-storage food is interested to know the temperature of the food along the supply chain for every fixed time interval, that buyer can send a Java class (or classes) to the corresponding Savant(s). The buyer configures the Java class sent and the Savant will function as instructed by the Java class.

This kind of dynamic Savant Services update encourages automation of supply chain as the supply chain can answer to any queries of a buyer or consumer automatically without any human intervention.

However, there are a few challenges that deter the development of dynamic Savant Services update. The first issue is the security problem. Allowing an anonymous user to upload unknown executable script onto the system is making the system vulnerable to malicious codes. Prevention on hackers attack on the system through malicious code will become difficult.

The second challenge is the stability of the entire system. If at the same time, there are too many people requesting the same Savant to carry out different tasks, the stability of the Savant may be affected, resulting in system failure. Though this can be avoided by queuing requests in a buffer, the determination of a sensible buffer size to avoid wastage of resource overhead will be very challenging.

## 10. Conclusion

This paper has introduced the technology and concepts of the EPC Network and presented some supply chain scenarios involving the EPC Network technology. The EPC Network concept has opened a gateway of solutions for supply chain management. From inventory management to product validation and authenticity detection, this concept has brought the supply chain management a significant step forward. The EPC Network is still a concept under constant development to provide a promising future of a high efficient supply chain.

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