A Proposal for Inter-Enterprise Communication of RFID Event Data

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Submitted to the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Logistics

at the

Massachusetts Institute of Technology

June 2005

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Abstract

Inter-enterprise communication of RFID event data requires rules and consistency. To create those rules and consistency one has to understand the requirements for the event architecture. I identified fifty-one stakeholders and thirty touch points in a textile supply chain from manufacturer in China to retail in The United States. Each of the stakeholders has different requirements for accuracy of the read data. After calculating a rough estimate of data quantity, I reduced data by setting some standards for aggregation and creating a mathematical model for inference and communication of read accuracy. I discovered that by dividing data requirements into two types, *summarized event data* and *detailed exception data and business forms*, I could meet all the stakeholders' needs. The solution was to implement a hybrid publish/subscribe architecture and service oriented architecture.

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1 Introduction

Inter-enterprise communication of RFID event data requires rules and consistency. To create those rules and consistency one has to understand the requirements for the event architecture. I gained that understanding by creating a list of stakeholders in a typical China to US textile supply chain.

The process of compiling the list of stakeholders in the supply chain brought to mind the fact that each of the stakeholders has different requirements for accuracy of the read data. For example, Customs officers want more accurate data than is necessary for shipping companies. Therefore, I created a way to communicate the quality of "less than perfect" read events, with each stakeholder considering his own risk tolerance at a given read location or "touch point".

To create a description of the data to be communicated, I researched the who, what, when, where and why of data requirements. I used that information to glean a rough estimate of raw data quantity.

After calculating a rough estimate of data quantity, I began to explore ways to minimize the amount of data on the network. I reduced data by setting some standards for aggregation and creating a mathematical model for inference. I also discovered that by dividing data requirements into two types, I could meet all the stakeholders' needs. The first type of information includes the small quantities of summarized, inferred and aggregated data that are provided to many recipients by a publish/subscribe architecture. The second type consists of large quantities of detailed information that is provided when exceptions are noted. These exceptional requirements are best served by service oriented architecture. By implementing a hybrid publish/subscribe architecture and service oriented architecture, I created a way to handle the two distinct information types.

1.1 Thesis Motivation

The introduction of Radio Frequency Identification (RFID) to the supply chain has generated considerable interest among software vendors, academicians and practitioners. Practitioners and software vendors are now creating heterogeneous proof of concept RFID systems for their respective supply chains. Despite their seeming promise, this research uncovered no systematic efforts to ensure interoperability between these heterogeneous implementations. Because of this, individual RFID architectures are in danger of becoming isolated from one another. Every new trading partner will have to create custom solutions to integrate into existing systems. This research proposes a scalable global architecture for the collection and dissemination of RFID Event Data. It is intended that this architecture be extensible to other types of event systems.

To do this, five standards must be defined:

- The "Event Space".
- A standard for aggregation and inference.
- A method for determining and a metric for communicating the quality of aggregated data.
- The interface between the "Event Space" and other entities.
- A mechanism to provide aggregated data continuously and granular data on demand.

Additionally, the architecture must be developed in such a way that three types of data; *raw tag data, aggregated tag data* and *business level information* can be effectively communicated among enterprises. The first type to be considered is the raw tag data, as read and reported by the tag reader. A summary of this data must be 'pushed', that is, sent without being requested, to all potential data consumers.

Raw tag data can be subdivided into four types: item, case, pallet and container. The format for the transmitted data remains constant for all four types. The only thing that changes is the level of aggregation and the quantity of data to be transmitted.

For example, tag data for individual item tags need not be transmitted when the items are contained within a case. In that situation, only the case level raw tag data will be transmitted. Again, the format of the case tag data is the same as for item tags. The only difference is that the data volume is lower when item data is sublimated within case data. Similarly, individual case data will be irrelevant when the cases are part of a pallet that has a tag. And again, the format of the data remains the same, only the quantity is reduced. The final opportunity to aggregate tag data occurs when we load the pallets into trucks or containers, which may also have their own tags.

However, the fact that item level information can be sublimated within case level information for the purpose of transmission does not imply that tag level information can be discarded. Tag level data must be persistent somewhere in the information system, so that it can be accessed if needed. This research discovered no clear advantage in any data storage location. The point is that we do not transmit the data unless it is needed.

The second type of data that needs to be transmitted is business level data, such as advance shipment notice and bills of lading. This data is also transmitted as a 'push' type of transaction.

The third type of data is again raw tag data, but it is encapsulated as a response to a 'pull'. That 'pull' would come in the form of, "I see a problem with that last bolus of pallet information. Could you send me all the data about the cases on that pallet?" The request for such information is passed to a web services server which will then query the local repository and provide the requested information. Once again, the quantity of *pulled* data is orders of magnitude larger than the data *pushed* by publish/subscribe.

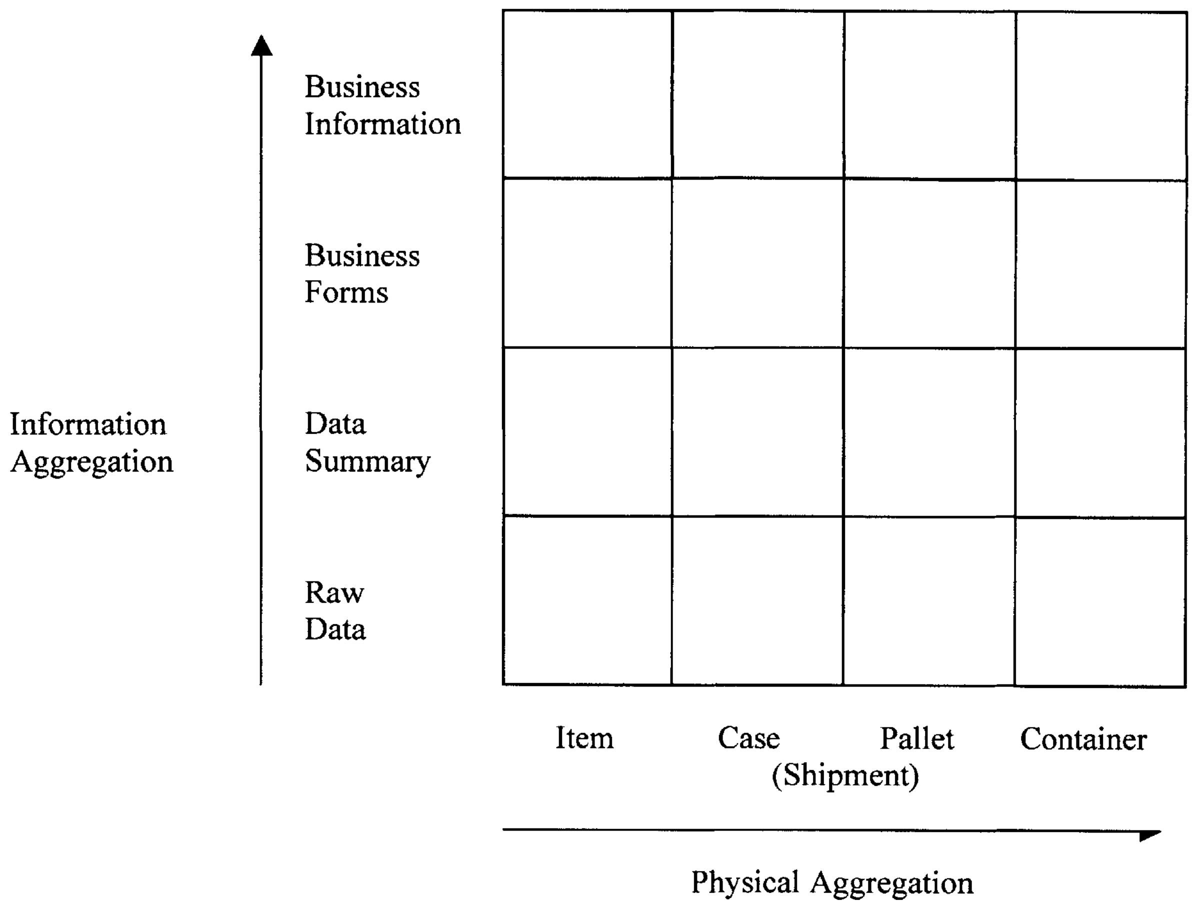

Figure 0 Data can be categorized by several axes. In this case I categorize data by physical aggregation and by information aggregation. Information can range anywhere from 1s and 0s of binary code to concepts and wisdom of business strategy. Aggregation can range from no aggregation to aggregation into that nebulous thing called a shipment.

Because these types of data are quite different, the architecture for their dissemination should, perforce, be different, each tailored to a specific type of data. As it happens, we can divide the information into two types. This division will help us to decide how to disseminate the information. One way to divide the information is to ask the question, "Is all of this data necessary, or can we summarize it somehow?" The answer is that the vast majority of RFID data can be stored in the local repository, while summaries are sent out on a regular basis.

But, how do we know if the summary is "good enough"? The answer, of course, lies with the recipient of the information. Therefore, what we need to send along with the data is some sort of measurement of how "good" it is. Once we have agreed on a standard of "goodness", it is up to the recipient to decide if the data is "good enough". For this reason, I created a weighted average that takes into account both the objective *risk* and the subjective *risk tolerance* of each stakeholder at each touch point. If a certain package of information it is not good enough, the recipient simply requests (via web services) that the all of the data that has been summarized in the message that is in question be resent in its granular form, at which time the recipient can analyze the data and take action if necessary.

1.2 Methodology

The Definition of the "Event Space", the interface between the "Event Space" and the mechanism for sharing data was created by the author based on knowledge gained from TIBCO® real time architecture training and on currently accepted practices of web service architecture. The standard for aggregation and inference was devised by the author through consultation with academic and industry experts.

Synthesis of existing scalable frameworks was the primary method for the creation of the Event Architecture. Scalable architectures have been created for wireless sensor networks, grid computing, distributed computing and battlespace simulation. Elements of each of those structures was incorporated and synthesized into a proposed worldwide, scalable architecture for the collection and dissemination of RFID Data.

1.3 Business Review

EPC™ Tag Data Standards Version 1.1 Rev.1.24 has been ratified and readers are improving effectiveness daily. These improvements are being achieved through multiple reads from multiple readers, multiple reads as pallets are turned on turntables, and through selective location placement of tags on items, cases and pallets. There are however certain physical limitations that are difficult to overcome. For example, liquid and metals and any other materials containing free electrons impede the performance of passive RFID tags (Pappu, 2005).

As of January 2005, most practitioner and software company effort is being focused on the creation of prototype systems arranged between individual retailers and their individual suppliers. Practitioners and software companies are moving quickly to put together systems to take advantage of RFID to improve information sharing and streamline supply chains. For example, Wal-Mart and Proctor and Gamble have created such a prototype utilizing IBM Websphere (Clauss, 2005). Other corporations have made similar relationships, but all will have difficulties when faced with the daunting task of utilizing RFID data to streamline processes through government barriers such as Chinese and Hong Kong customs and the U.S. Government's Container Security Initiative. The practitioners must create custom solutions for each port of entry and each customs point. This scalable architecture simplifies this effort and creates a geometric reduction in the labor expended for custom data interchange.

1.4 Literature Review

Academic research on RFID up to 2005 has been primarily focused on the creation of effective reading devices and the standardization of tag data. It is therefore necessary for event architecture research to catch up to and surpass industry. With my scalable global architecture, practitioners and software vendors have a strong framework on which to build their RFID systems.

The High Level Architecture (HLA) was finalized in 1996 as an architecture on which the Joint Synthetic Battlespace was built (IEEE Std 1516-2000, 2000). HLA allows federations of agents to join other federations in a Joint Synthetic Battlespace. These entities join federations, announcing their behaviors and beginning to interact with other entities (IEEE STD 1516.1-2000, 2000). The federations, in turn, join other federations announcing their behaviors and commencing interaction. My architecture creates "Event Spaces" and allows them to join and leave other "Event Spaces" at will. These "Event Spaces" can act as subordinates, peers or superiors to other "Event Spaces".

The growing ubiquity of unswitched fiber networks allows for the consideration of a connectionless real-time architecture (Orincek 1996). Because fiber optics provide high bandwidth and reliability, unswitched fiber networks are ideally suited for multicast and broadcast. By creating a connectionless real-time architecture, issues of scalability and latency have been addressed and difficulties alleviated.

Grid computing also holds promise for large scale architecture (Foster, et al, 2001). Grid computing is "...a large system of networked computers whose processing power used to solve difficult and time-consuming problems" (Lexico, 2005). Unfortunately, one of the challenges facing the Open Grid Services Architecture is the lack of support for intermittently connected mobile grid services (Atkinson, 2003). Additionally, what is required for real time event architecture is not tremendous computing power, but vast quantities of scalable bandwidth. While Open Grid Services Architecture is an interesting concept, the value of grid computing architecture within this research is to provide some ideas for the creation of a large scalable architecture. It was not my intent to build the architecture for the grid, but to research the concepts of grid architecture, utilizing gleaned understandings to improve the efficiency and efficacy of the global Event Architecture.

The National Research Council of National Academies Press describes the layered architecture as one in which the interface between the layers is like the neck of an hourglass, with the wide part of the hourglass being the layers themselves. This visualization facilitates seeing the layers as being potentially vast, whereas the interface between the layers must be narrowly defined (National Research Council, 1994). This formulation was useful in the creation of the global Event Architecture.

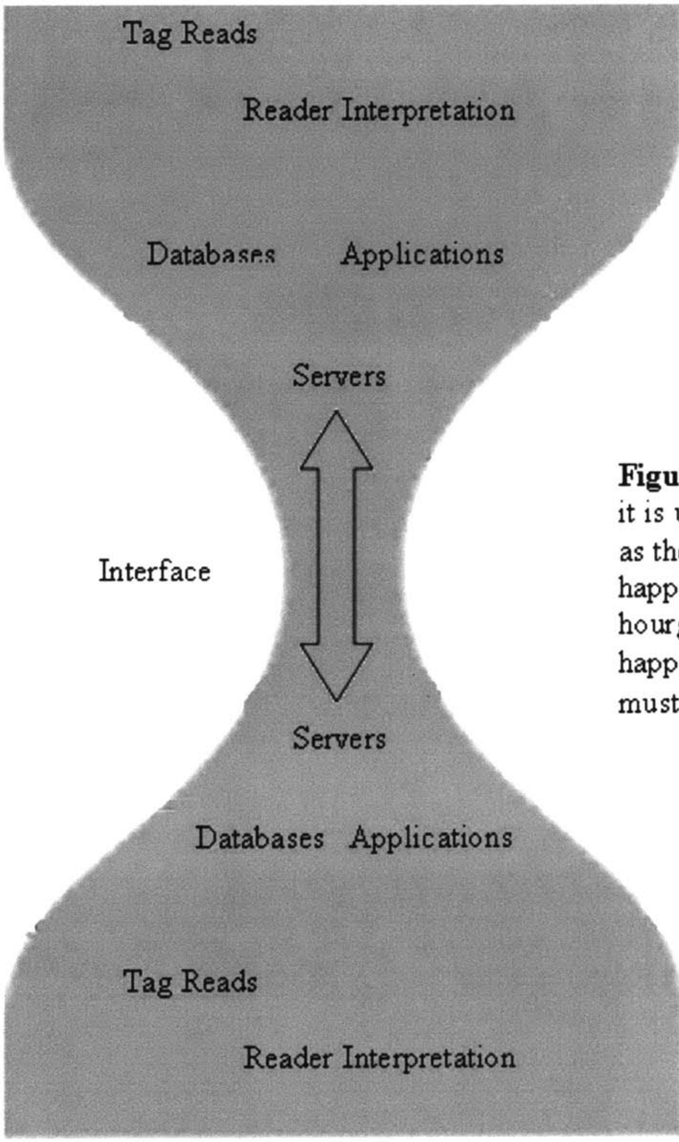

Figure 2 In a layered architecture, it is useful to think of the interface as the neck of an hourglass. What happens within the wide part of the hourglass is indeterminate. What happens at the neck or interface must be tightly defined.

2 Stakeholders/ Use Cases and Political Ramifications

The central questions driving adoption of RFID are "Why do we want perfect supply chain visibility?", "Who wants it?" and "Specifically, what information do they want?" The following section explores who the stakeholders are, what information they want and why they want it.

2.1 Stakeholders

International supply chains are complicated and dynamic. RFID holds promise for gaining visibility into the supply chain. The first question to be addressed is, "Who are the stakeholders?" Also, "Are there others who are interested in increasing the transparency of the international supply chain?", "What do they want to know?" and "Why?" By answering these questions I built a business case, which in turn helped me to define the architecture. I used the example of an international supply chain with manufacturing taking place in China and retail sales in The United States. While I do not claim to provide an exhaustive list of stakeholders in the supply chain, I have alerted the reader as to the varied interests of supply chain stakeholders. Of paramount interest was the fact that nearly half of the stakeholders in the international supply chain today, are not the players we usually anticipate in a supply chain. They are government entities of one type or another. Theses government entities have a strong interest in many of the touch points in the international supply chain. Their interests arise for reasons of national security, tax collection, immigration, intelligence, material safety, drug enforcement and trade and commerce.

The following narrative is clearly illustrated by Exhibit 1, Supply Chain Stakeholders.

A Narrative Description of Stakeholders

The first stakeholder I considered was the retailer, who may want to know the status for his order at any point in the supply chain. He wants this information to help in his supply and demand planning. "What is my pipeline inventory?" and "When can I expect its arrival?" are the key questions for which he wants answers. He also wants to know what is happening inside his store. "What is in the back room?", "What is on the floor?', "Where is the left-handed widget?" "What is being purchased?" and "What is leaving the store?" are key questions to be answered by a comprehensive supply chain management (SCM) solution.

I next considered the wholesaler, whose needs are very similar to the retailer's, except that because he usually has less control over demand planning, he needs to exercise more control over supply planning. In some cases the wholesaler may want to employ vendor managed inventory (VMI). In that case, he will want downstream as well as upstream product location data.

Third Party Logistics (3PL) providers and other incidental manufacturers who provide value added services such as tagging, reboxing, dying and labeling want upstream data for production planning. The 3PLs want data for the entire supply chain for which they are planning logistics. Trucking companies want to know where their trucks are, what is on the trucks and where they are going. They also want to know if pickups are going to be ready on time. If they know that a pickup in going to be late, they may reroute their trucks to maximize utilization.

Distribution Centers (DCs) want to know what is happening within the DC, but they may also want to know about DC arrivals and departures.

Manufacturers' stake in the supply chain runs the gamut from production to sales. Often manufacturers would like to have a comprehensive view of the pipeline, especially if they are doing VMI. By viewing the entire supply chain, they make their production more regular. RFID can also aid to quickly create a bill of lading as products pass through the dock door.

Government offices in source countries, destination countries and every county through which the products transit want to know the contents of every container, truck and ship that passes. By creating supply chain foreknowledge and visibility through information sharing of transit events they become more effective and efficient in their work.

RFID Event Data sharing allows the shipping company (SC) to gain knowledge of exceptional cargo and in so doing makes his ships safer. The SC can use global location to keep track of its ships. The Harbormaster and port facility manager also utilize shipment information to schedule and arrange placement and movement of ships and containers.

There are also third parties with a financial stake in the supply chain. Insurance underwriters and issuers of letters of credit have a vested interest in the contents and location of shipping containers.

In addition to the legitimate stakeholders listed above there are stakeholders to whom we want the supply chain to remain invisible. Pirates, who still exist on today's high seas, want to know the location of valuable goods. If unsecured RFID data traffic were intercepted by pirates, they could use the information to steal valuable cargo. Terrorists and smugglers want to be able to access and modify the data stream coming from containers, thereby covering their tracks.

2.2 Following the Supply Chain

In order to complete a list of touch points and stakeholders, I began at the manufacturer and followed a typical item, for example a hand-held electronic game, from its manufacture in China, to its sale in a retail store in the US. My purpose was to identify most of the stakeholders in a real world supply chain. In so doing, I created to create a scalable, responsive Event Architecture that will be useful to as many entities as possible. An Event Architecture is a hardware and software architecture designed to collect, disseminate and store event data in real time.

The following graphic (Figure 3) illustrates events and their locations in the retail supply chain chronologically:

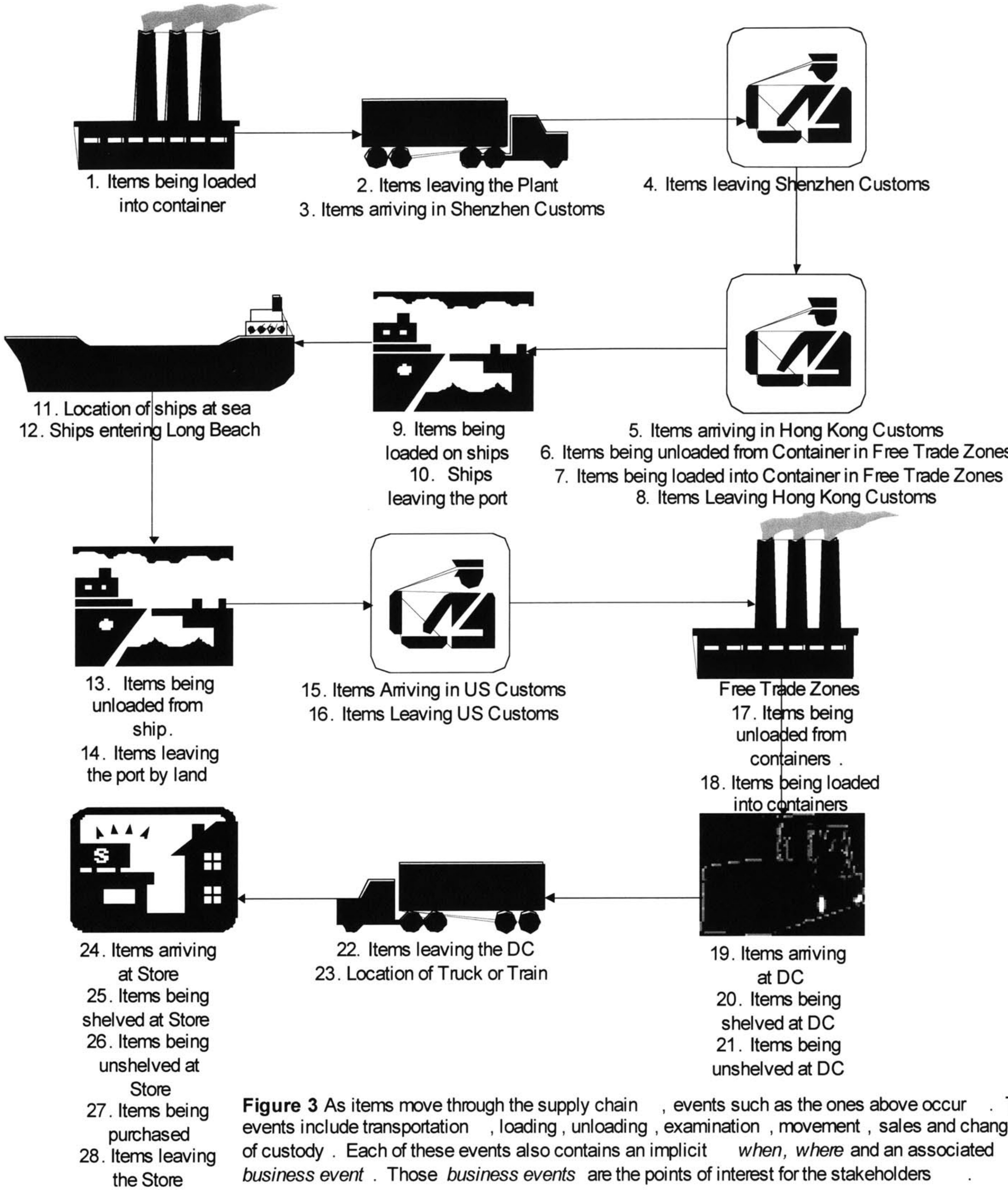

Figure 3 As items move through the supply chain, events such as the ones above occur. These events include transportation, loading, unloading, examination, movement, sales and changes of custody. Each of these events also contains an implicit *when, where* and an associated *business event*. Those *business events* are the points of interest for the stakeholders.

The spreadsheet included as Exhibit 1 provides another view of the events and stakeholders in the China-US supply chain. The stakeholders are on the horizontal axis and the events in which they are interested are on the vertical axis. Most stakeholders have a stronger interest in the events before they take custody than in the events after they release custody. They have an *urgent* interest in important and critical events that immediately precede their taking custody of the shipment. In a broad view, one can see the sweep of *urgent criticality* moving through the supply chain ahead of the shipment. This is illustrated in red in the Exhibit 1.

The manufacturer, wholesaler and retailer have interest throughout the entire supply chain, especially if they intend to exercise influence over the supply chain. The defining events, which are the events that define the contents of shipments, containers, pallets or cases, are of interest to *all* supply chain stakeholders.

2.3 Governmental Ramifications

As one can see from the table of stakeholders (Exhibit 1), government entities have a strong interest in the supply chain. I have divided the governmental agencies into six categories; Security and Justice, Immigration, Trade and Commerce, Materials, Intelligence and Others. Two international organizations, the World Trade Organization (WTO) and the World Health Organization (WHO) also have an interest in this supply chain.

A key question to be addressed is who is entitled to what information. It is beyond the scope of this research to define this, but it will have to be addressed within each supply chain. Another key question, the question of privacy, is directly related. This too is beyond the scope of this research.

However, the government has a vested interest in gaining access to as much of this information as possible. Security and Justice entities want access to the information to protect the safety and interests of the United States Government and citizens. Immigration Organizations want to reduce illegal immigration and protect the health and wellbeing of people trying to immigrate to the United States. Trade and Commerce Organizations, such as the WTO, the IRS in the US, and revenue agencies in other countries want to enforce treaties and regulations and collect taxes. Hazardous Materials officers of various governments and corporations want to know if there is anything dangerous in any container. Government entities associated with food and agricultural safety want to ensure that no invasive insects, illnesses or pathogens enter the country. The Bureau of Alcohol Tobacco and Firearms wants to make sure that none of those items enter the country illegally or without being properly assessed their taxes. Intelligence services, such as the CIA, FBI and NSA in the US and the Ministry of State Security (MSS) in China have a powerful interest in containers entering and leaving their countries. It will be up to Human Rights and Civil Rights groups to curtail the intrusion made possible by the combination of RFID technology and regulations (Homeland Security Initiative and the Patriot Act) recently passed by the US Congress.

3 How much data? — A Reasonable Approach to Reducing Data Volume

The listing in Section 2.2 of information required from a typical supply chain gave me a starting point for estimating the amount of data that would pass through it. Data in the supply chain can come in many forms, from information about individual items to aggregated data about pallets, trucks and containers to business level information such as advance shipment notices and bills of lading. In this section, I outline data dimensions, movement decisions and required flexibility. I then enumerate and explain ways to reduce data volume.

Data Dimensions

Although supply chain information has many characteristics, addressing physical aggregation and information aggregation is sufficient to define the information architecture. These other dimensions include cost, usefulness, importance, urgency, stasis, dynamism, and ease of use. However, using just these two criteria, information aggregation and physical aggregation, allows for a multitude of different data types (See Figure 1). Consideration of the other data criteria should inform, but not dominate decisions about how to handle the data.

Data Movement Decisions

I categorized the need for and manner of movement of data. The chief consideration for deciding how to move the data was to ask the questions, "Can it be summarized?", "Is it needed constantly?" and "How many entities need the data?" By answering these questions I discovered a starting point for architecture for the collection and dissemination of event data.

Summarizing data allowed me to reduce the volume of data on the network. Knowing how often and how urgently data is needed helped me to decide how much latency is acceptable, how much bandwidth is needed and how frequently data needs to be delivered.

Flexibility

The architecture I created was useable for all the information types I mentioned earlier. It communicates business forms such as bills of materials and advance shipment notices as well as raw tag data. It moves aggregated data and inferred data. When it shares inferred data, it conveys the quality of that inference in an objective way. The question of quality of inference will be addressed in section 3.3

I have designed an architecture that is completely scalable with existing network technology for the foreseeable future. I achieved this by dispersing the network traffic over the entire network, never burdening any single circuit. In the intermediate term, there will be neither a "bandwidth glut" nor a "bandwidth scarcity" (Coffman, 2001). In the longer term, I anticipate that bandwidth availability will continue to outpace this event architecture's bandwidth growth.

3.1 Potential Data Volume

Having looked at the sources and sinks of data in the supply chain and examined the different types of data, I made a rough estimation of the data volume. The calculation that follows at the end of this section is based on the attached spreadsheet. It approximates the amount of data in a typical supply chain from manufacture in China to sales in a retail store in the United States.

According to Ravi Pappu, in a presentation to MIT on February 17, 2005, Wal-Mart sells 620 million items per day or 226 Billion items per year. That number provided the starting point for data quantity calculations. I chose to calculate the total number of potential bits as a starting point. In a later section, I will demonstrate why all of those bits do not need to be passed through the network.

Rough estimate of potential data volume based on Wal-Mart's FY 2004 Sales (in 000s)	
Sales (Wal-Mart, 2004)	$ 256 billion
Units (Pappu, 2005)	226,000,000
	0
Bits @ 1 tag per unit & 96 bits per tag	21,696,000,000
Case bits @ 12 units per case	1,808,000,000
Pallet bits @ 80 cases per pallet	22,600,000
Truck bits @ 64 pallets per truck	353,125
Container bits @ 40 pallets per container	565,000
Bits annually for Walmart reading each item one time	23,527,518,125
One time event bits daily for Walmart (365 working days per year)	64,458,954
Event bits annually, assuming 30 read events in a typical supply chain	705,825,543,750
Event bits daily, assuming 365 working days per year	1,933,768,613
Event bits daily from non-store reads, assuming 365 working days per year and running 24/7 at each read location	1,611,473,844
Event bits daily from store reads, assuming 365 working days per year and running 24/7 at each read location	322,294,769
Event bits per second from non-store reads, assuming 365 working days per year and running 24/7 at each read location	18,651
Event bits per second in the 3/4 of stores running 70 hours/week, assuming 365 working days per year	6,714
Event bits per second in the 1/4 of stores running 24 hours/day, assuming 365 working days per year	933
Event bits per second in each store, assuming 3551 Stores in the US (Wal-Mart, 2004)	2
Total event bits per second	26,298

Table 1 The table above gives us a rough estimate of the amount of RFID data Wal-Mart would have in its supply chain data system if it were to RFID tag all of its items from manufacture to retail.

3.2 Data Reduction through Aggregation

I proposed reducing data by aggregation. When you first load a case with items, you read the items as you put them in the case. If you tag the case as well as the items, you can *aggregate* the items within the cases. At this point, any information sent over the network can be limited to aggregated information. Once it has been established that a case contains certain items and the case remains sealed, there is no need to send item information over the network. Individual item information will re-enter the data stream at the point that items are disaggregated from cases. Similarly, cases can be aggregated into pallets, and pallets into containers or trucks and if need be, containers into ships.

3.3 Data Reduction through Inference

One of the central considerations within companies currently seeking to implement RFID is what to do about the fact that current reader technology is generally less than 100% effective. If the antenna is not tuned for the tag frequency, the reader might not be effective at all. This brings up a central question. "Do you need 100% read rate for RFID event data to be useful?"

For many uses, you do not need a 100% read rate. You can infer from the read of a pallet that the cases are on the pallet, even if not all of the cases are seen by the reader. When a case is loaded with homogeneous items or a pallet is loaded with homogeneous cases, they are typically loaded in a very organized way. This organization can help us to decide how useful our read is. For example, if we keep track of which cases are on the inside of the pallet and which cases are on the outside of the pallet, we can weigh our reads differently. We are less likely to miss a read on a case on the outside of the pallet than we are on the inside. Therefore, there is more cause for alarm if an expected read of an outside case is missed than if an inside case is missed. There may, in fact, be no cause for alarm at all if a read is missing from the inside of the pallet. A missing read from the outside of the pallet is more likely to mean that a case has been lost or stolen. This inference can be further supported by the application of seal tags on the pallet. A seal tag is a tag that will stop functioning if the seal on the pallet is broken. Thus, reads that demonstrate the existence of a functioning seal tag and the existence of all of the tags known to be on the outside of the pallet may provide us with a very high assurance that the full pallet is intact, even if not all of the tags are read at any given point in the supply chain.

The question is, "How do we know that the assurance level is 99% and not 92%?" The answer is that every supply chain will have to develop its own heuristics for creating its standards. Those standards will have to be agreed upon by all of the stakeholders who share the data. As a starting point, I recommend creating a weighted average. The question to be addressed is how does one decide how much to weigh reads from the inside of the pallet and how much to weigh reads from the outside of the pallet?

The weight factor is calculated ahead of time by testing the read rate with a fixed pallet configuration. To create the weight factor, read the pallet configuration a fixed number of times, noting the percent of successful reads. For example, if you read an inside box 40 out of 100 times, its percent of successful reads (a/n) is .40. The weight factor is calculated as

Equation (1.1) $W_i = a/n + (1 - a/n)(CRTF)$, where

a = number of successful reads during test *and*

n = number of attempted successful reads during test *and*

CRTF = Contextual Risk Tolerance Factor = (ORF*SRF) $0 \le CRTF \le 1$ *and*

ORF = Objective Risk Factor, as defined below *and*

SRF = Subjective Risk Factor, as defined below.

The following is a methodology for determining the weight factor for each tag at a location in which the pallet can be turned on a stretch wrap turntable surrounded by tag readers. First, place RFID tags on the cases in the orientation in which the inside cases are most likely to get an effective read. Second, load the pallet in an organized way, taking care to place the cases according to a specified, documented load plan. Third, turn the pallet on the stretch wrapping machine around which are strategically placed tag readers. (The readers are organized such that together they form one logical reader as far as information systems are concerned.) Fourth, make note of which tags are read consistently and which ones are missed.

If, with the above described tag orientation, a significant number of outside reads are missed in addition to missed inside reads, reconsider tag positioning. Reposition the tags and repeat test until outside read effectiveness is maximized, hopefully reaching 100%.

Once desired effectiveness for outside reads is reached, load several pallets in a similar way, adding seal tags to the pallets. Turn those pallets on the stretch wrapping machine, noting which tags are read. Some tags are missed more consistently than others. Calculate the weight factor as above. Those tags that are missed consistently carry less weight in Equation (1.2) that follows.

As stated before, the Weight Factor includes both objective risk and subjective risk tolerance. Because different business processes have different risk I created the Contextual Risk Tolerance Factor (CRTF). The CRTF is calculated by using a combination of the subjective risk factor (SRF) and objective risk factor (ORF). The objective factors can be determined using Pareto

Analysis combined with an empirical cumulative distribution function to perform an ABC classification. (Arsham, 2005) Although it is conceivable that a B item in one stakeholder's context is an A item in another stakeholder's context, in most cases the ABC Classification holds up across organizations. The Weight Factor includes this assumption.

The purely subjective factor, risk tolerance, is related to the business process. Certain business processes are inherently more risky than others. For example, less than truckload shipments typically go through consolidation center. "During the consolidation process there is constant risk that the goods will be left behind or loaded onto the wrong truck" (Dinning, 2002). There is a greater risk in the consolidation center than there is within a company's own warehouse. The SRF will be a number between zero and one.

Each reading location will share the actual number of reads and the available number of reads and the reading methodology with those fellow supply chain stakeholders who have a direct interest in this touch point. Those stakeholders examine the methodology and determine their own CRTF heuristically. Once they have determined their own CRTF, they can calculate their own Q using Equation (1.2).

I have proposed that the CRTF be calculated by multiplying the subjective factor, SRF times the objective risk factor, ORF related to ABC analysis. A table of objective risk factors follows:

	Scenario 1		Scenario 2		Scenario 3	
	% of items in SC	ORF	% of items in SC	ORF	% of items in SC	ORF
A	20%	0.2	10%	0.1	15%	0.15
B	50%	0.5	70%	0.7	40%	0.4
C	30%	0.7	20%	0.8	45%	0.55

The benefit of including the subjective risk factor is that enterprise-wide business rules can be applied to all supply chain touch points. For example, a company might apply the rule that any time the Q value from Equation (1.2) is below a certain value, an alert is generated notifying that the associated touch point event must be examined by human intervention.

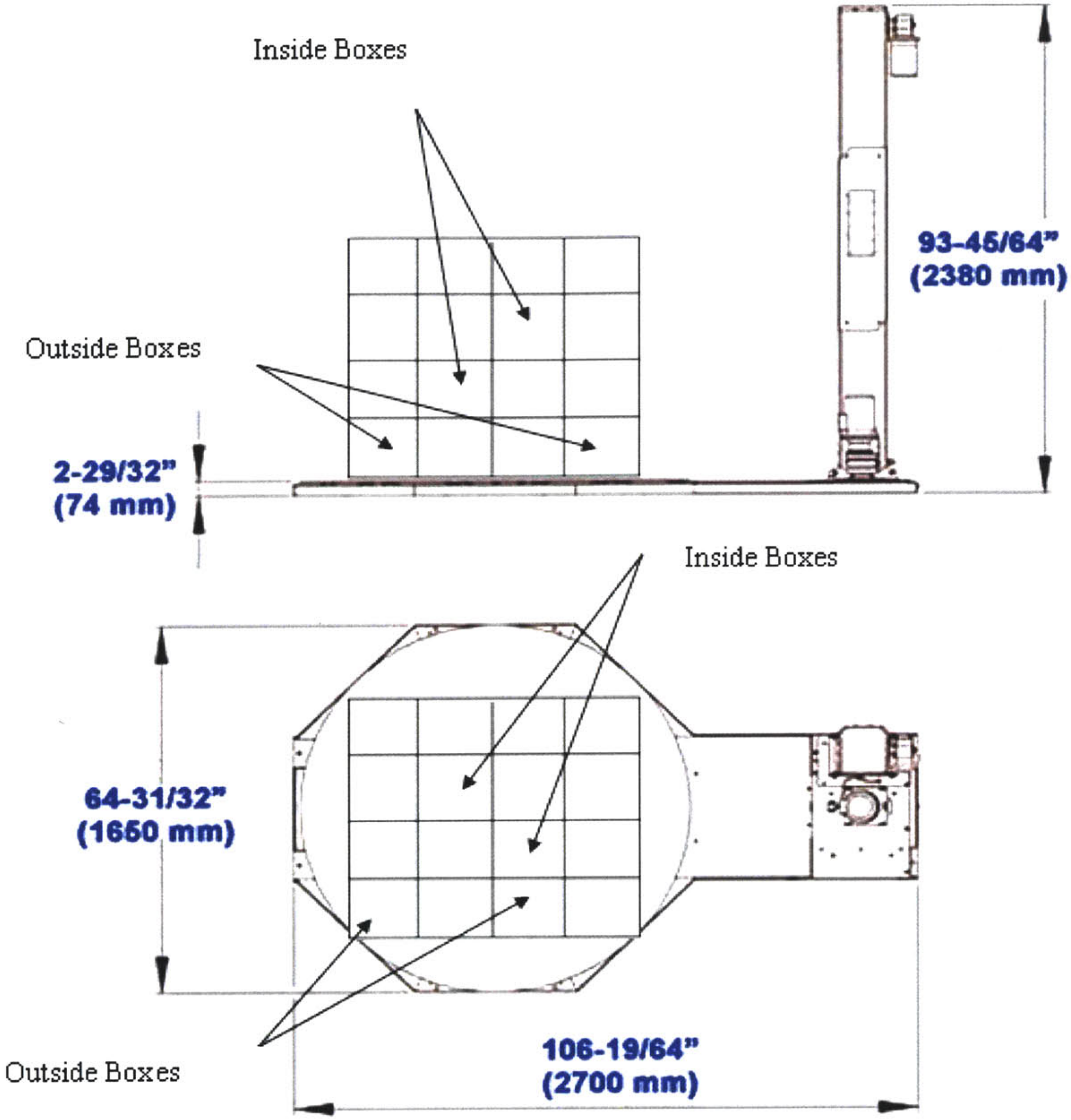

Figure 5 When we turn the pallet on the stretch wrap turntable , we are more likely to get reads on the outside of the pallet . By giving the reads different weights, we can develop a measurement of quality that we can share with our supply chain partners .

Source: http://www.capspackaging.com/english/machinery/semi-automatics/workhorse.html with modifications by the author .

The quality equation is based on a general equation for weighted average:

$$Q = \frac{\sum_{i=1}^{n} R_i \bullet \frac{1}{W_i}}{n}$$ **Equation (1.2)** A quality measurement based on weighted average.

Where Q = Quality

W_i = Weight Factor, i.e. Expectation of a good read $0 \le W_i \le 1$

R_i = Read or not read – Binary 0 or 1

n = Potential number of reads

We now have a method for sharing data and a common measurement of data quality. We also have a measurement that we can use within our own organization, applying business rules to make decisions. In addition to sharing data, stakeholders should reach a level of service agreement with each other. With this methodology, less than perfect reads lead to useful information shared across the entire supply chain.

I have now suggested a method by which we can *infer* the presence of all items even though we have less than perfect reads.

Data Reduction

By *aggregating* items into cases and cases into pallets and by *inferring* that a good seal tag read and a good pallet read are sufficient to imply the presence of all the items on the pallet, one need only publish or broadcast the information related to the pallet rather than the information related all of the items on the pallet. If we assume that a typical pallet contains eighty cases each containing twelve items then the total number of potential reads can be calculated as (80 cases*12 items) + 80 cases + 1 pallet + 1 pallet seal or 1042. Since, in most cases the existence of a good seal tag and pallet tag are sufficient to demonstrate the presence of the pallet full of cases, one can send only the pallet and pallet seal tag data on the network. The reduction in tag reads on the network can be calculated as (80*12) + 80 – 2 or 1040. By inferring that the seal and pallet tag are a necessary and sufficient substitute for individual item reads of every item on the pallet, data volume is reduced by a factor of 521 for the described situation.

3.4 Data Reduction through Publish/Subscribe Paradigm

This volume can be further reduced by multicasting event data. Multicasting involves sending one copy of a particular message to many recipients. Individual copies of the message are split off from the original at various junctures in the network. This serves to more evenly spread the data across the network, as follows:

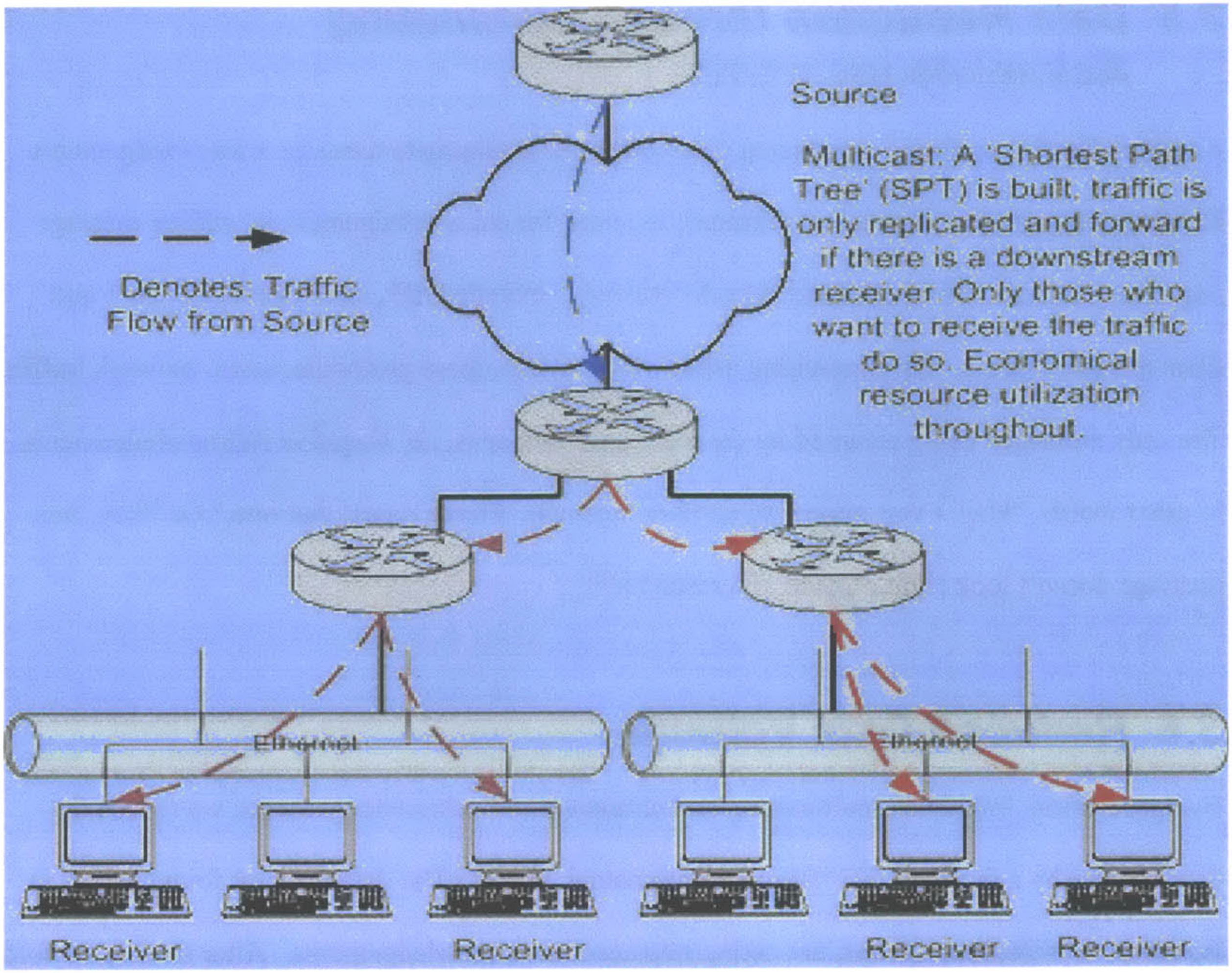

Figure 6 Multicasting and broadcasting reduce volume on the source network and allow copies of messages to branch off to many different destination networks.

Source: http://www.geant.net/server/show/ConMediaFile.730

Data Reduction

By unicasting to each of the interested parties, one would send data to at least 52 entities as listed on spreadsheet Table 1. By multicasting, data volume is reduced by a further factor of 52.

3.5 Data Reduction through Eliminating Acknowledgements

Another effective method for reducing data volume is to eliminate message acknowledgements. Existing messaging protocols that eliminate the need for acknowledgement by adding message sequence numbers and/or checksums to the messages include UDP, fiber channel Class 1 and fiber channel Class 3. By eliminating acknowledgements, these protocols reduce network traffic. The only messages being returned by the recipients are nacks, i.e. Negative Acknowledgements. In other words, "Hey, I was expecting another message. Please repeat that one." Or "Hey, that message doesn't look right. Could you resend it?"

3.6 Reduced Data Volume

By aggregation, inference, multicasting and elimination of acknowledgements, we reduce the data volume by a factor of 521*52 or approximately 27,000. The data flow we found earlier in Equation was 26,000,000 bps, not taking into account acknowledgements. After the 27,000 fold reduction, the data flow is approximately 1000 bps for the entire network.

4 The Federation & Event Space

Because there are two basic kinds of data, summarized and detailed, we need two ways to move the data. According to my stakeholder analysis, the summarized data needs to be sent to as many as 52 stakeholders, probably more, since we have undoubtedly missed some. The summarized data, therefore, is composed of a large number of small pieces of data that will be sent to a large number of recipients. Those pieces of data may include advice that other pieces of data are available on demand. They will also include the Q measure and CRTF that we defined earlier. In either case, the receiving entity will apply business rules to those pieces of information and if required will activate the other element of my architecture, *Web Services*. *Web Services* are web based services that provide data in many formats to requesting entities. The requesting entity queries the Web Service according to agreed syntax and the Web Service responds with the requested information is a predefined format. To reiterate, I will use a publish/subscribe methodology for real-time summarized data and web services architecture for on-demand detailed data.

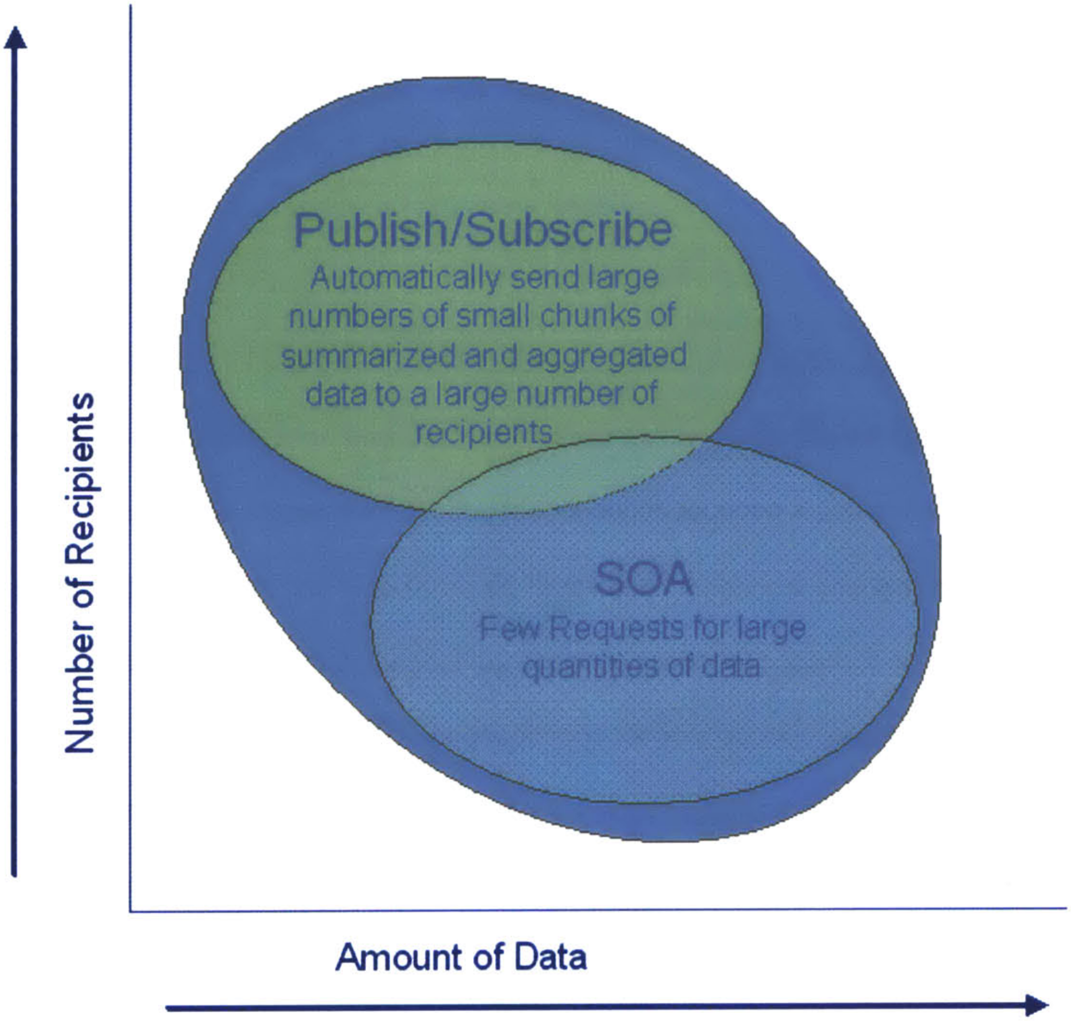

Figure 7 The Web Service Architecture performs effectively for request and response from individual stakeholders, while the publish/subscribe Event Driven Architecture provides the day to day summarized data needed by many stakeholders.

4.1 Overview of Players and Boundaries

The players within each event space are entirely up to the owner of the event space. An event space is an autonomous area in which RFID read events take place. Event spaces range from warehouses to enterprises. (See Figure 8) Typically, RFID readers read items, cases, pallets etc. and send the data to a reader interpreter (ex. EPC ALE Device). A reader interpreter is a device that accepts reader inputs, perhaps from multiple readers, and applies logic to the data received. For example, if it receives fifteen reads of the same item, it will pass on to outside entities such as databases the fact that the item is there, not that it is there fifteen times. The reader interpreter sends the massaged data to a data store (ex. Database). An application server draws data from the database and provides it to an internal web server, which then sends the data to users at workstations inside the event space. The application server also draws new data from the database, issuing publication orders to the publisher/subscriber. Finally, the web services server answers external requests, queries the database and responds to the request.

In order to emphasize the fact that only the interface need meet a particular standard, I proposed the following: The tags themselves might be barcodes, handwritten labels, and emitters of phased neutrino pulses or any other identifying technology you can imagine. The event generator can be a barcode scanner, or a person manually reading the label on each and every item. That data can be manually input into a database, a spreadsheet or a sheet of paper. In the end, however, the data must be transmitted over the wire according to publishing standards and web service requests must be answered according to service agreements.

As mentioned earlier, there will be two components of interface between the event space and the federation: A Publishing/Subscribing Server and a Web Services Server. The Publisher/Subscriber will handle routine traffic of small messages to a large number of recipients. Web Services will provide a mechanism by which users can request detailed information on an ad hoc basis. In other words, the Web Services component will send large messages to a small number of recipients. This hybrid architecture will work just as well for granular event data as it will for data summarized in such formats as bills of lading, advance shipment notices, etc. Another strength of this architecture is its scalability. One can see from and Figure 9 below that by summarizing and aggregating data, one can add federations within and around federations ad infinitum.

The physical architecture can be easily modified to include EDI, XML, Binary, etc. The publisher simply publishes in those formats, wrapping the data within a header and footer as in Section 4.3.

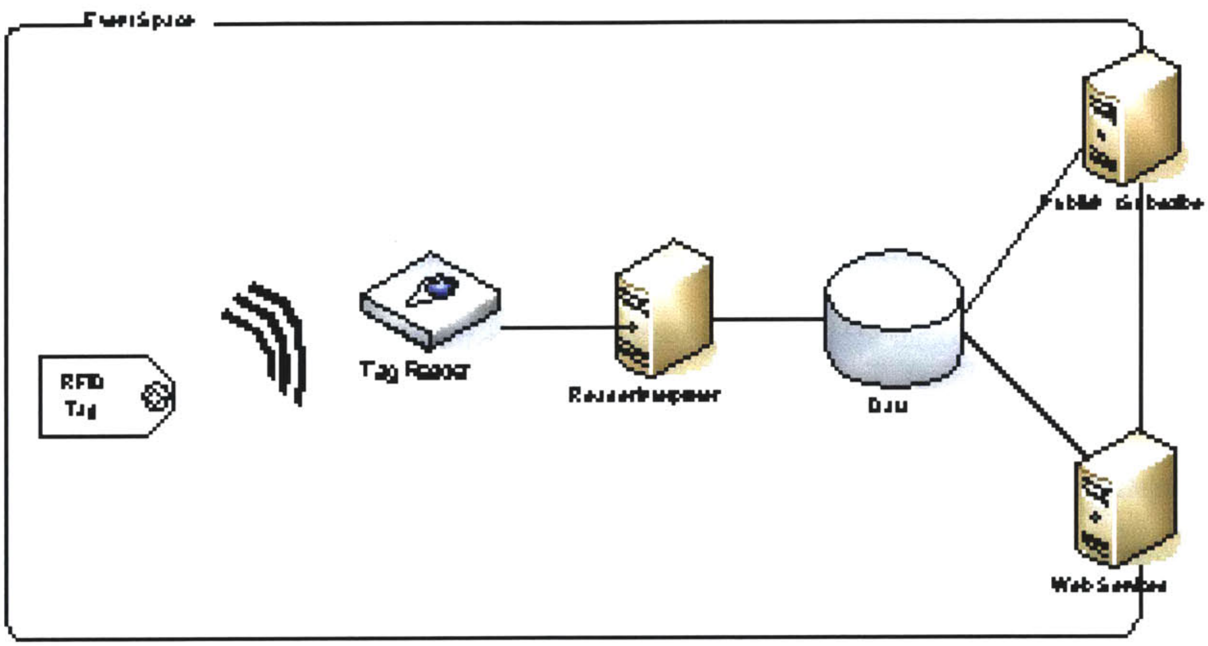

Figure 8 Each Event Space shares its data with other entities via Web Services Architecture and Publisher / Subscriber Architecture. The Web Services Architecture performs effectively for request and response from individual stakeholders, while the publish / subscribe Event Driven Architecture provides the day to day summarized data needed by many stakeholders.

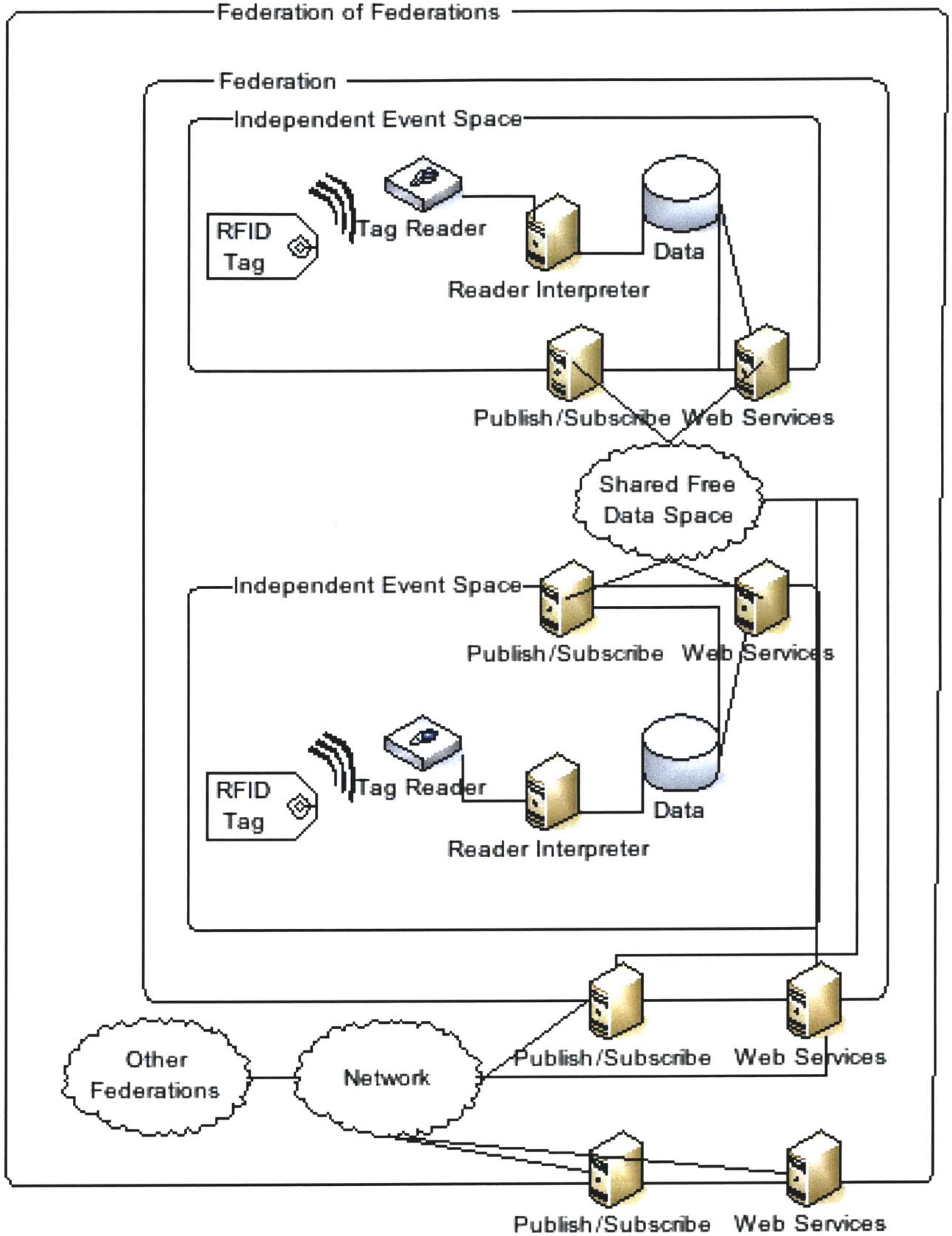

Figure 8 The Independent Events Spaces join federations, sharing data with other stakeholders as appropriate. The federations can, in turn, join other federations

4.2 Web Services

Web services will be used in this architecture to take care of exceptional events. Web services are programmatic interfaces made available via the World Wide Web. (Booth, 2004) They are defined more precisely by W3C as : "...a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards." (Booth, 2004)

Earlier, I wrote of the need for a narrowly defined interface between entities. In February, 2004 W3C finalized its Web Services Architecture (W3C gen), providing that standard well-defined interface. It also allowed for the wider part of the hourglass when it stated,

> "A Web service is an abstract notion that must be implemented by a concrete agent. (See Figure 3) The agent is the concrete piece of software or hardware that sends and receives messages, while the service is the resource characterized by the abstract set of functionality that is provided. To illustrate this distinction, you might implement a particular Web service using one agent one day (perhaps written in one programming language), and a different agent the next day (perhaps written in a different programming language) with the same functionality. Although the agent may have changed, the Web service remains the same. (Booth, 2004)

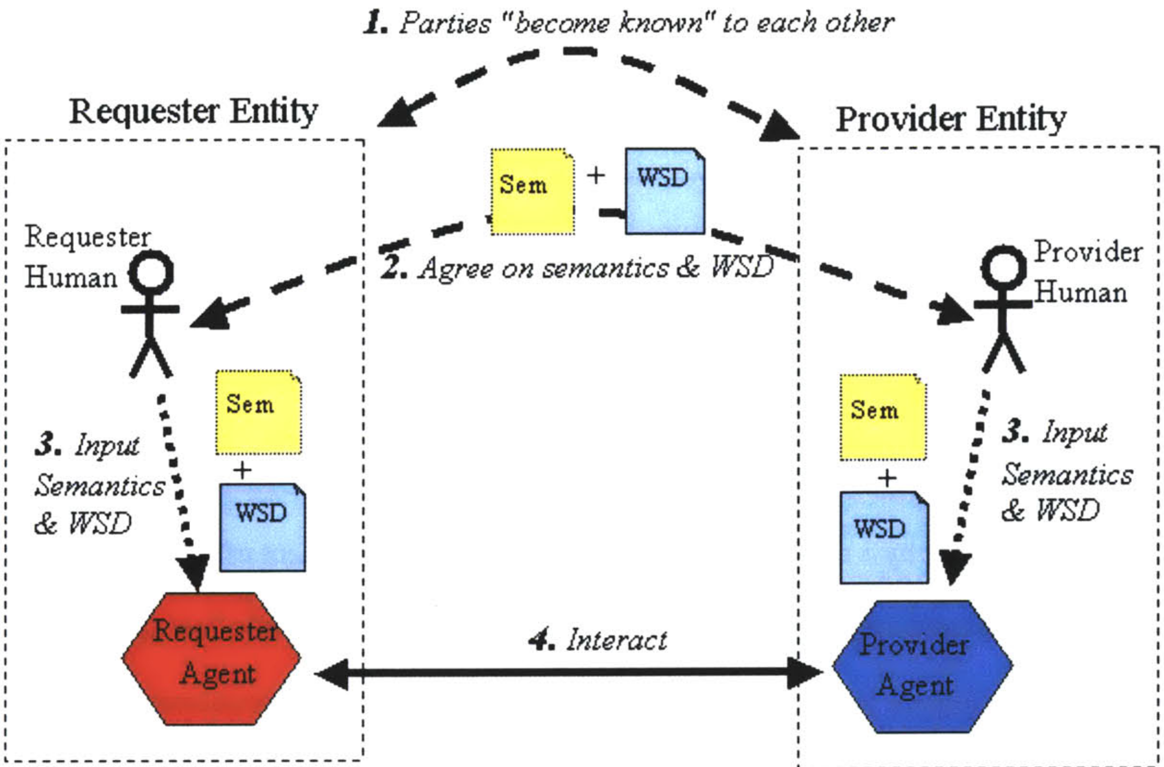

Figure 2 Web Services Architecture is based on agreements between the Requester and the Provider of Web Services.

4.2.1 Granular Data vs. Aggregated Data

Web services work as well with granular data as they do with aggregated data or business documents. A business can make Advance Shipment Notices or a list of all EPC codes in a shipment available via web services. The business can choose to make the format of such web service documents public or share it only with its business partners.

4.3 Publisher/Subscriber

As I stated before, the publisher/subscriber deals with aggregated, summarized and inferred data and with notifications of the availability of detailed records. In other words, the publisher/subscriber sends small amounts of data to a large number of customers. A typical packet would look like this:

Subject	Serial Number	Payload	Length	Checksum

Figure 3 -- Subscribers will subscribe by subject name, the subject name will imply a pre-arranged format for the payload. The serial number is used to ensure that all messages are received in order. The payload can be in any agreed format. The length and checksum will be used to ensure integrity of the message itself. c.f. TIBCO Rendezvous Messages

4.3.1 Definition of Method

The first message sent out by a new publisher/subscriber is the announcement of its presence in the federation. These announcements have a defined subject name, for example "new.player", so that all subscribers recognize immediately that the message is an entrance announcement.

All messages are sent out with a defined subject name. The header indicates what kind of data is contained in the message. Each recipient subscribes to messages that have a given subject name. A subject naming convention must be created within each federation and shared with the chosen recipients. By keeping the subject naming convention in a secure central repository, all authorized stakeholders are able to read and write according to permissions defined in the level of service agreement.

4.3.1.1 Granular Data vs. Aggregated Data

Either granular or aggregated data can be sent out by publication, however, it is anticipated that most summaries, aggregations and notices will be published because they are items that will be needed in real time. The publish/subscribe architecture is a real-time, event driven architecture. Detailed granular data will be provided by the Web Services Architecture on an ad hoc basis.

This keeps large volumes of data local, and sent over the network only when necessary. The publishing server provides notice that the detailed information, as summarized in the published messaged is available on demand.

4.4 How the Event Spaces and Federations Interact

As alluded in the previous section, the event spaces and federations interact by publishing, subscribing and requesting and providing web services. Supply chains are about people. (Cizmeci, 2005) Technology is a way to automate what people agree to. Level of service agreements and Web Service Agreements define the semantics. Each is shared with supply chain partners according to business rules.

5 Conclusion

In this research I have provided a list of 52 stakeholders in a typical China to US textile supply chain. One noteworthy item is the fact that approximately half of the stakeholders are government entities. Those entities provide no consumer value in the traditional view of the supply chain. The process of compiling the list illuminated the need for a definition of accuracy of the read data. Many of the stakeholders can make use of "less than perfect" read quality. I created a weighted average that considered both objective risk and subjective risk tolerance. This weighted average, when submitted along with a contextual risk tolerance factor (CRTF) is necessary and sufficient to share data and create business rules in a meaningful way.

By learning the who, what, when, where and why of data requirements I created a description of the data to be communicated That information was a starting point for a rough estimate of raw data quantity.

After calculating a rough estimate of data quantity, I explored ways to minimize the amount of data on the network. I reduced data by setting some standards for aggregation and creating a mathematical model for inference. I discovered that by dividing data requirements into two types, I could meet all the stakeholders' needs. The first type of information includes the small quantities of summarized, inferred and aggregated data that are provided to many recipients by a publish/subscribe architecture. The second type consists of the large volumes of detailed information that is provided when exceptions are noted and when required by business rules.

These exceptional requirements are best served by service oriented architecture. By implementing a hybrid publish/subscribe architecture and service oriented architecture, I created a way to handle the two distinct information types.

My research also uncovered opportunities for further research:

- The issue of aggregation of unlike items
- The notion of the ownership of information
- The need to address security issues
- The automation of Publisher and Web Service Discovery
- The exact format of publisher/subscriber packets
- When turning pallets on a stretch wrap machine, we can discern which orientations are most likely to get the most complete and accurate reads. We can then use that information to set up readers and orient pallets at other locations in the supply chain. We can also use that information to select tags and readers.
- More detailed mathematics for calculating the CRTF

Glossary

- 3PL – Third Party Logistics Provider, i.e. Third party companies that provide logistics services for companies.
- EPC – Electronic Product Code OR Shorthand For EPC Global the global standards body for electronic Price Codes
- Event – Just as it sounds…an event…specifically an event that we would like to capture.
- Event Space – A contained area in which events take place.
- HLA – High Level Architecture, a standard
- IEEE – Institute for Electrical and Electronics Engineers
- JSB – Joint Synthetic Battlespace, Conforming to IEEE 1516
- Pull – An architecture in which data is requested from data sources by data recipients
- Push – An architecture is which data is sent from a data source without being requested
- RFID – Radio Frequency Identification
- Touch Point – An event in the supply chain that is of interest to the stakeholders and from which data can be garnered

Acknowledgements

I would like to offer my profound gratitude to my advisor and friend, Dr. David Brock, Founder of the Auto-ID Center and the MIT Data Center. His deep insights into the future of Auto-ID are found throughout this narrative. His constant supervision and support were central to the success of this project. The notions of *aggregation* and *inference* would not have been included in this thesis without his having introduced the concepts to me.

I am deeply grateful and forever in debt to Dr. Chris Caplice, Executive Director of the MLOG Program at MIT. His decision to admit this middle aged man to the program has fulfilled a longtime dream and forever altered the course of my life. I cannot thank him enough.

Finally, and most importantly, I thank my beloved wife Nancy, who sacrificed much more this year than I. Her indefatigable support made this achievement possible. Nancy, you are the greatest!

Exhibits

Exhibit 1 Supply Chain Stakeholders
Exhibit 2 RFID Event Data Sources

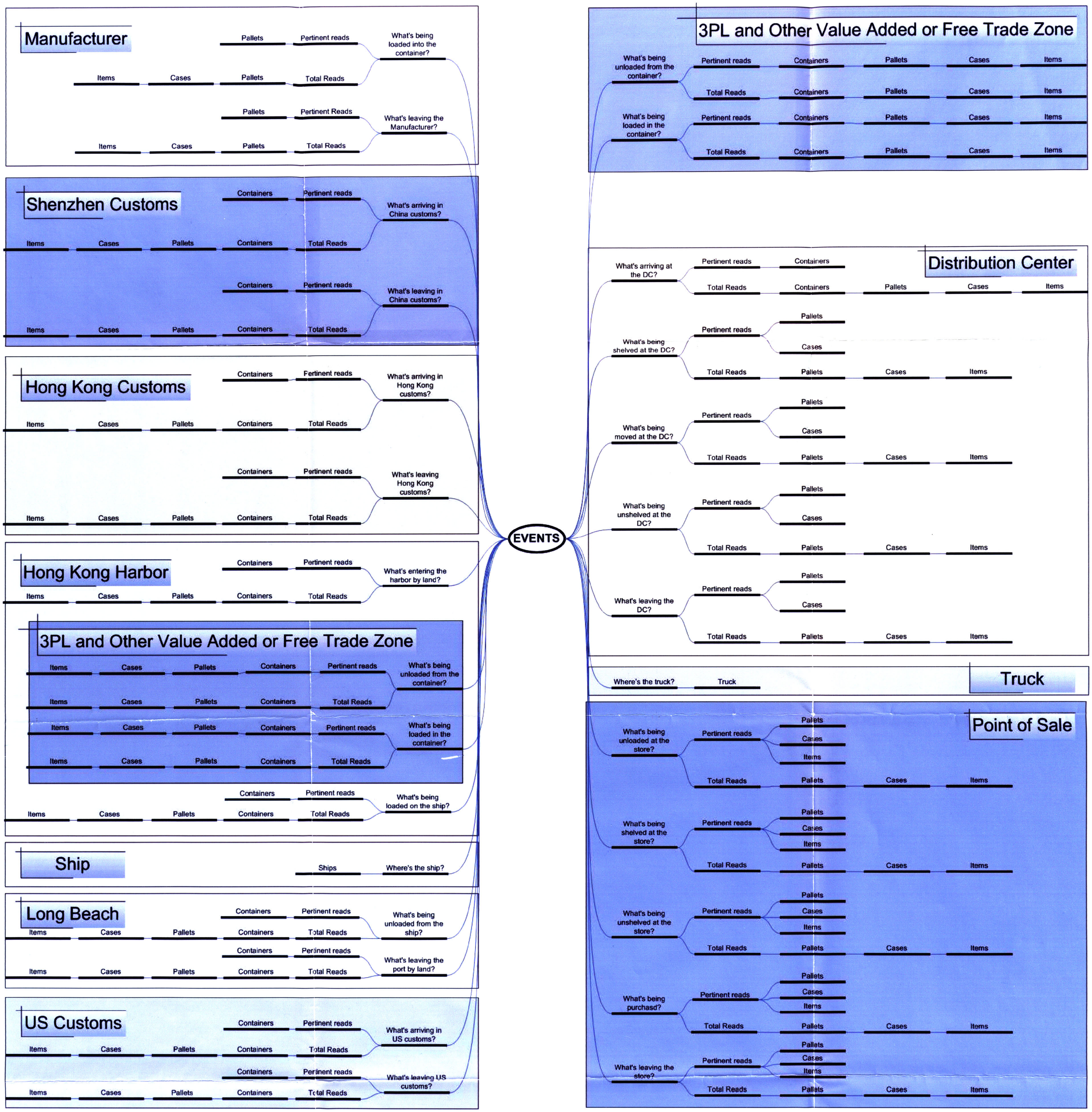

Figure 4 This diagram lays out all sources or RFID Event Data at each read location, the pertinent data at each read location and the business event at that location

NOTE: 3PL and Free Trade Zones have been shown both within and outside port areas.

Stakeholders (Data Collection Events × Stakeholders)

Location	Event (or sublocation)	Sublocation Event	Manufacturer	Issuers of Letters of Credit	Insurance Underwriters	Shenzhen Customs	Hong Kong Customs	Hong Kong Harbor	3PLs	Value Added Manufacturers	Harbormaster HK	Port Facility Manager HK	Shipping Company	Pirates	Terrorists	Smugglers	Security and Justice: Homeland Security	Security and Justice: DoJ	Security and Justice: CSI	Security and Justice: DoD
Manufacturer	Loading into container		U,C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Departure		U,C	I	I	U,C	I	I	I	I	I	I	I				C	C	C	C
Shenzhen Customs	Arrival		I			U,C	U,C	U,I	U,I	U,I	U,I	U,I	U,I				I	I	I	I
	Departure		I			U,C	U,C	U,I	U,I	U,I	U,I	U,I	U,I				I	I	I	I
Hong Kong Customs	Arrival		I				U,C	U,C	U,I	U,I	U,I	U,I	U,I				I	I	I	I
	Departure		I				U,C	U,C	U,I	U,I	U,I	U,I	U,I				I	I	I	I
Hong Kong Harbor	Arrival by land		I					U,C	U,C	U,C	U,C	U,C	U,I				I	I	I	I
	3PLs, Value Added Locations and Free Trade Zones	Arrival	I					I	U,C	U,C	U,C	U,C	U,I				I	I	I	I
		containers	I						U,C	U,C	U,C	U,C	U,I				I	I	I	I
		Loading into containers	C	C	C			U,C	U,C	U,C	U,C	U,C	U,I	C	C	C	C	C	C	C
		Departure	I					U,C	U,C	U,C	U,C	U,C	U,I	C	C	C	C	C	C	C
	Loading onto ship		I					U,I			U,C	U,C	U,C	U,C	U,C	U,C	C	C	C	C
	Ships leaving port		I					U,C			U,C		U,C	U,C	U,C	U,C	C	C	C	C
At Sea	Location of ship		I										U,C	U,C	U,C	U,C	C	C	C	C
Long Beach	Ships entering port		I										U,C		U,C	U,C	U,C	U,C	U,C	U,C
	Unloading from ships		I										U,C		U,C	U,C	U,C	U,C	U,C	U,C
	Departure by land		I												U,C	U,C	U,C	U,C	U,C	U,C
US Customs	Arrival		I												U,C	U,C	U,C	U,C	U,C	U,C
	Departure		I												U,C	U,C	I	I	I	I
3PLs, Value Added Locations and Free Trade Zones	Arrival		I												U,C	U,C	I	I	I	I
	Unloading from containers		I												U,C	U,C	I	I	I	I
	Loading into containers		I												U,C	U,C	I	I	I	I
	Departure		I												U,C	U,C	I	I	I	I
Distribution Center	Arrival		I														I	I	I	I
	Shelving		I														I	I	I	I
	Moving		I														I	I	I	I
	Unshelving		I														I	I	I	I
	Departure		I														I	I	I	I
On the road	Location of Truck/Train		I														I	I	I	I
Point of Sale	Arrival		I														I	I	I	I
	Shelving		I														I	I	I	I
	Unshelving		I														I	I	I	I
	Purchase		I														I	I	I	I
	Departure		I														I	I	I	I

Location	Event (or sublocation)	Sublocation Event	Immigration Authorities: Immigration (INS)	Immigration Authorities: Citizenship (USCIS)	Materials: HazMat Officers	Materials: ATF	Materials: Food Safety (FSIS)	Materials: FDA	Materials: DOA	Materials: WHO	Materials: NIH	Materials: DEA	Materials: CDC	Trade and Commerce: WTO	Trade and Commerce: Commerce (DOC)	Trade and Commerce: NAFTA	Trade and Commerce: IRS	Intelligence: US Customs (C-TPAT)	Intelligence: CIA	Intelligence: FBI	Intelligence: NSA	Intelligence: Geo-Spatial Intelligence (NGA)	Others: Emergency (FEMA)	Others: Environmental (EPA)	Others: US Coast Guard
Manufacturer	Loading into container		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Departure		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Shenzhen Customs	Arrival		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
	Departure		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Hong Kong Customs	Arrival		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
	Departure		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Hong Kong Harbor	Arrival by land		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
	3PLs, Value Added Locations and Free Trade Zones	Arrival	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
		containers	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
		Loading into containers	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
		Departure	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Loading onto ship		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Ships leaving port		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
At Sea	Location of ship		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Long Beach	Ships entering port		U,C	U,C	U,C	U,C	U,C	U,C	U,C	C	U,C	U,C	U,C	C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C
	Unloading from ships		U,C	U,C	U,C	U,C	U,C	U,C	U,C	C	U,C	U,C	U,C	C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C
	Departure by land		U,C	U,C	U,C	U,C	U,C	U,C	U,C	C	U,C	U,C	U,C	C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	
US Customs	Arrival		U,C	U,C	U,C	U,C	U,C	U,C	U,C	C	U,C	U,C	U,C	C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	U,C	
	Departure		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	
3PLs, Value Added Locations and Free Trade Zones	Arrival		I	I	I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Unloading from containers		I	I	I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Loading into containers		I	I	I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Departure		I	I	I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
Distribution Center	Arrival		I	I	I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Shelving				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Moving				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Unshelving				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Departure				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
On the road	Location of Truck/Train				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
Point of Sale	Arrival				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Shelving				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Unshelving				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Purchase				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	
	Departure				I	I	I	I	I	I	I	I	I		I	I	I		I	I	I	I	I	I	

Location	Event (or sublocation)	Sublocation Event	Authorities (AAPA)	Long Beach Harbor	Harbormaster US	Port Facility Manager US	3PLs US	Value Added Manufacturers US	TL & LTL Carriers	Rail Carriers	Distribution Centers	Wholesaler	Retailer
Manufacturer	Loading into container		C	C	C	C	C	C	C	C	C	C	C
	Departure										I	I	I
Shenzhen Customs	Arrival										I	I	I
	Departure										I	I	I
Hong Kong Customs	Arrival										I	I	I
	Departure										I	I	I
Hong Kong Harbor	Arrival by land										I	I	I
	3PLs, Value Added Locations and Free Trade Zones	Arrival									I	I	I
		containers									I	I	I
		Loading into containers	C	C	C	C	C	C	C	C	C	C	C
		Departure									I	I	I
	Loading onto ship										I	I	I
	Ships leaving port		I		I	I					I	I	I
At Sea	Location of ship		U,C	C	U,C	U,C	I	I	I	I	I	I	I
Long Beach	Ships entering port		U,C	U,C	U,C	U,C	I	I	I	I	I	I	I
	Unloading from ships		U,C	U,C	U,C	U,C	U,I	U,I	I	I	I	I	I
	Departure by land		U,C	U,C	U,C	U,C	U,I	U,I	I	I	C	C	C
US Customs	Arrival		U,C		U,C	U,C	U,C	U,C	U,I	U,I	I	I	I
	Departure						U,C	U,C	U,C	U,C	C	C	C
3PLs, Value Added Locations and Free Trade Zones	Arrival						U,C	U,C	U,C	U,C	I	I	I
	Unloading from containers						U,C	U,C	U,C	U,C	I	I	I
	Loading into containers						U,C	U,C	U,C	U,C	I	I	I
	Departure						U,C	U,C	U,C	U,C	U,C	U,C	U,C
Distribution Center	Arrival								U,C	U,C	U,C	U,C	U,C
	Shelving										U,C	U,C	U,C
	Moving										U,C	U,C	U,C
	Unshelving										U,C	U,C	U,C
	Departure										U,C	U,C	U,C
On the road	Location of Truck/Train										U,C	U,C	U,C
Point of Sale	Arrival										U,C	U,C	U,C
	Shelving										I	I	U,C
	Unshelving										I	I	U,C
	Purchase										I	I	U,C
	Departure										I	I	U,C

Each Stakeholder will define its interest in two parameters: Urgency and Importance

Urgent = U	Urgent and Critical
Critical = C	Urgent and Important
Important = I	Critical
	Important

For convenience, I have shown 3PLs, Value added Manufacturers and Free Trade Zones *within* Hong Kong Harbor and *outside* Long Beach Harbor. These activities can actually take place inside or outside of harbor areas on both continents.

Thanks to Chaitra Chandrasekhar of MIT for sharing her list of government stakeholders.

Exhibit 1 - Supply Chain Stakeholders *- There are thirty* stakeholders identified in a typical supply chain from manufacturer in China to retail sales in the United States. This spreadsheet identifies their level and urgency of interest in each of the events in the supply chain. Their interests are described as 'Urgent and Critical', 'Urgent and Important', 'Critical' and 'Important'.

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