Transactional Model of a Company based on the Hub-Spoke and LDPC/MIMO Models

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Abstract— This paper offers a description of a new transactional model designed for a m-commerce 4G architecture, and the economic benefit that it can bring to an organization. For the design, it has been used a Hub and Spoke transport model for the material flow, a Queuing model for the bank company transactions flow, and a LDPC/MIMO channel for the transmission environment. With the new system, the SNR can be reduced approximately in 8 dB, which makes possible a greater rapidity in the transactions. The global results show an economic gain of at least a 20.12%, because of the redesign of the conversations, the optimization of the Transport Problem using the Hub and Spoke Model and the reduction in the errors of the sent data.

Keywords— Transaction, Conversation, MIMO (Multiple- Input, Multiple-Output) channel, LDPC (Low-Density Parity-Check), Hub and Spoke Model and Optimization

1. Introduction

The motivation of this paper is to evaluate a design of a new transactional model to implement the 4G technology, and also to evaluate the economic impact. In the literature most of the 4G designs fall in technical details without any concern related with implementation issues and the optimization of the channel is made only from the physical architecture, codification codes, modulation codes and channel code. In reference [1] B. Yeah and L. Hanzo explained a reduced-complexity turbo detector for convolutional-coding aided space-time trellis coded (STTC) schemes from the technical point of view only. On the other hand, the economic evaluation of a new technology in the companies have restrictions about equipment, training of personnel, legal restrictions and other related to the organization [2]. Other restrictions are not evaluated, like those ones caused by the way of communication, for example, a lost of signal that increases the time of communication of the call, increasing then the total time of the transaction (accumulated sum of conversation timing of the transaction cycle). This kind of disturbances is despised because the cost associated to them is low and difficult to quantify.

From the m-commerce point of view, in the literature are found some designs and evaluations of applications[3]. In these designs the economic transactions are repeated as one of the main dimensions, which is logical because the investigated issue is trade. The problem is that they do not approach other important dimensions as conversations (information flows) that allow to make contracts, the environment through these regular communications are made, and the transport structure in which physical goods are exchanged.

This paper analyzes the problem to minimize the total costs of shipment considering the own restrictions of the channel by which the transaction is made, improving the four mentioned dimensions, named generically as: physical structure, conversational structure, channel structure and economic transactions structure. To make this economic evaluation, different methods have been used in order to analyse each structure, such as System Dynamics [4], Linear Programming and transaction process using Workflow. In fact, the material flows problem was modelled using a transportation model and the 4G conversations were modelled using Workflow inspired by Medina and Flores model to make an organizational design, supposing that the business as an order/supply structure with a principal conversation from which other conversations are originated [5]. Also in order to model the high speed local access point, this paper considered a MIMO system with two antennas in the transmitter and a receiver with two antennas [6].

This paper is organized as follows: Section 2 describes the specification of the problem in the company. Section 3 presents the system description. The section 4 shows the problem solving. The results are presented in Section 5. And finally, conclusions are given in the last section.

2. Problem Formulation.

The problem started in a case study in which an export company that sends fresh fish to The European Union and it needs optimise the supply chain. Once caught the fish is transported by different routes. Each route has a cost associate and a specific number the resource that will be sent to the international market, this number is different in each month and it is different for each supplier.

The loading process in the Air-terminal, consist in receive of the product (boxes) according to the requirements of the airline; these requirements are then transmitted to the cargo handlers who then load the airplanes. While they are loading the aircraft the arrangements are made for departure. At the end of this process it is sent to an EU. The reception in the EU is made by agents of the cargo agency, who transfer by truck the loads until market, where the client receives the shipment. If the costumer is satisfied with the product, he accepts the transaction. For this reason, in the realization of the transaction process there are delays given by the time of negotiation of conditions and amounts of the consignment, physical transport of the product, and the time of the bank transaction.

This it is a typical problem of transport that can be optimized using a transport model diminishing the total cost, nevertheless, there are restrictions that habitually not considered, but they are important at the time of making the commercial interchange and are the number of transactions that are made in a cycle of the business. If one can establish in less time greater number of transactions can increase the number of trips, making possible that the variable costs lower and introducing a new variable to the system that is employee of the channel that is used.

In this paper a case study has been used to evaluate, using empirical data, a new transactional model that use a LDPC/MIMO channel, through an economic evaluation.

3. Systems Description

In the Export Companies it is fundamental to control the times of arrival at the airports to the predetermined hour. These require a great coordination with the Airlines that will transport the shipments. In the particular case of a cargo agency that sends an original product from distant territories, it is necessary to track the boxes, so that they end up where you want them. Figure 1 shows the Diagram of the Export /Import Process at the actual situation, where there are two associated bank for the transaction exchange. While Figure 2 shows the Diagram of the Export /Import Process in the New Company, in the future situation only one bank will centralise the transactions as a way to improve the benefit.

4. Problem Solving

An extension of the localization models are the net models Hub ad Spokes. These ones have the special feature of modelling problems with different kinds of services. In this case the services cover the goods and information transport from an origin to a destiny. Each origin-destiny couple represents a different service that must be delivered. For example, considering an airline service, the products transported from Chile to Spain are not interchangeable for the products transported from Chile to England or from USA to Chile.

4.1. Case 1. Present Model

The Present situation has been described in the figure 3. In this model there are only physical flows that centralize in one node and then are distributed to destiny. The central node is interpreted as a Hub node with six Spoke nodes. In this diagram the flows given by transaction, conversation and channel architectures are not incorporated because they are no longer incorporated to the Organization.

4.1.1. First Model Formulation

The model for this situation is described:

Inputs:

H_{ij} : Demand or flow between the origin node i and the destine node j .
C_{ij} : Unitary cost for the movement of the demand between the node i and j .

Decision Variables:

X_k :1 if the node Hub is located in the node k .
0 in other case.
Y_{ik} : 1 if the node i is connected to a hub located in the node k .
0 in other case.

The Objective Function (15) minimizes the total cost of transport of the demand through an only one hub located in k . The demand from the origin node i to the destination node j (H_{ij}) is multiplied by the cost of going from the node i to the hub located in the node k and from this node up to the destination j ($C_{ik} + C_{kj}$).

$$Min \sum_{i=1}^{n}\sum_{k=1}^{n}\sum_{j=1}^{n} H_{ij}(C_{ik} + C_{kj}) Y_{ik} Y_{jk} \qquad (15)$$

Restrictions

$$\sum_{k=1}^{n} X_k = 1 \qquad (16)$$

$$Y_{ik} = X_k \quad \forall i = 1,...,n, k = 1,...,n$$

$$X_k \in \{0,1\} \quad \forall k = 1,...,n$$

$$Y_{ik} \in \{0,1\} \quad \forall i = 1,...,n, k = 1,...,n$$

4.2. Case 2. Future Model

The figure 4 represents the future situation, the node hub k, collects the demand of the nodes i joined it, Later this node transfers the flow for the channel hub to hub finally to distribute it to the destiny j. It is necessary to indicate that not always a hub realizes all the functions before mentioned, since if the origin node and the destiny node are in the same city, the hub does not realize the function of transmission of the demand.

It has been supposed that one integrates to the company of services the units of Compilation and transfer, besides the banking and the server who stores all the information related to the transactions. These units allow to the company to control the different flows of information, material and monetary without losing quotas of penalties for transaction or for lack of information.

4.2.1. Second Model Formulation

The model for this situation is described**:**

Inputs:
H_{ij} : Demand or flow between the origin node i and the destine node j .
d_{ij} : Distance between the node i and node j .

Costs:
α : Unitary cost of collecting for unit of distance and unit of demand.
β : Unitary cost of transferring for unit of distance and unit of demand.
γ : Unitary cost of distributing for unit of distance and unit of demand.

Decision Variables:
X_{ik} :1 If the node i connected to Hub is located in the node k .
0 in other case.
Y_{ik} : 1 if the node i is connected to a hub located in the node k .
0 in other case.

The Objective Function (13) minimizes the total cost of transport of the demand through 2 hubs and the assignment of the near nodes. The demand from the origin node i to the destination node j

(H_{ij}) is multiplied by the costs of collecting (αd_{ik}), transferring (βd_{kl}) and distributing (γd_{lj}).

$$Min \sum_{i=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} \sum_{j=1}^{n} H_{ij} \, (\alpha d_{ik} + \beta d_{kl} + \gamma d_{lj}) Y_{ik} \, Y_{jl} \tag{13}$$

Restrictions

$$\sum_{k=1}^{n} X_k = 2 \tag{14}$$

$$\sum_{k=1}^{n} Y_{ik} = 1 \quad \forall i = 1,...,n$$

$$Y_{ik} \le X_k \quad \forall i = 1,...,n, k = 1,...,n$$

$$X_k \in \{0,1\} \quad \forall k = 1,...,n$$

$$Y_{ik} \in \{0,1\} \quad \forall i = 1,...,n, k = 1,...,n$$

4.3. Architectures of the Problem

In the current situation, four relevant levels or architectures that allow the normal development of the activity have been identified. These architectures have been classified according to the kind of flow that they control. The first identified architecture is the physical one, related to the flows of goods that must be transported to their destiny. The second architecture is the related one to the conversations made by the company. There is not actually a concept related to this level, but it has emphasized for its importance in the information transmission that allow to agree in business. The third architecture is related to the channel through which every information flow circulate. To simplify the problem, it has been studied only the data transmission in a small radius, microcell, using a MIMO channel. Finally, it has been incorporated to the study an Economic Transactions level to investigate the economic flows behaviour and the benefit of the incorporation of a bank to the process.

4.3.1. Physical Architecture of the Company

In order to model the Physical structure it has been used the methodology of System dynamics. With this methodology have been identified the principal relations of the system to simulate the model of the present situation and the model of the future situation.

4.3.1.1. Conceptualization of the system

To understand the physical architecture is necessary to detect the principal influences that concern the system and to represent throw of a graphics the situation, in this case this graphs are the Influence Diagrams. The figure 5 shows the principal influence of the systems, for example with this diagram

4.3.2. Conversation Architecture

The intervention that has been made in a Cargo Agency has allowed the construction of an organizational structure able to use in an effective way the Conversational Processes, this processes represent the real structure of the transaction. Each conversation is one step in the supply chain, for this reason is important to resolve the problems caused by breaks of promises not fulfilled.

An unfulfilled promise produces delays in the transactions and possibly it can produce the end of the transaction. In the figure 7 is the workflow map that represents the conversational structure of the company. In the situation it is been necessary to evaluate a plan of improvement of the information channels throw of the Workflow methodology. This map has helped to calculate the averages times of every conversation and the costs for averages call to quantify the benefit in the organization.

4.3.3. Channel Architecture

The figure 8 shows a general description of the channel that it has been used for the communication between the New Company, the Supplier and the Customers. The data sent from the emitter are encoded and modulated so they can be sent through the MIMO channel. Since, the channel includes a LDPC codes for encoder/decoder process, a BPSK modulation and a wireless link that passes though an AWGN and fading of the signal. In that condition the signal must be demodulated and decoded so it can be received for the recipient.

4.3.3.1. MIMO System Model

It is considered a MIMO system with a transmit array of two antennas and a receive array of two antennas [6]. It was assumed flat fading between each transmit and receive antenna and also assumed that the channel is memoryless. The channel matrix at any given time t is given by [7]:

$$\mathrm{H}_t = \begin{bmatrix} \mathrm{h}_{1,1}^{t} & \mathrm{h}_{1,2}^{t} \\ \mathrm{h}_{2,1}^{t} & \mathrm{h}_{2,2}^{t} \end{bmatrix} \quad (1)$$

Where the jith element, denoted by $h_{j,i}^{t}$, is the fading attenuation coefficient for the path from transmit antenna i to receive antenna j.

At the receiver, we note that the signal at each antenna is a noisy superposition of 2 transmitted signals degraded by channel fading. At time t the received signal at antenna j, $j = 1,2$ denoted by r_t^{j} is given by:

$$r_t^{j} = \sum_{i=1}^{2} h_{j,t}^{t} s_t^{i} + n_t^{j} \quad (2)$$

Where n_t^{j} is the noise component of receive antenna j at time t, which is also i.i.d. Gaussian.

It is represented:

$$r_t = (r_t^{1}, r_t^{2}) \quad (3)$$

And

$$n_t = (n_t^{1}, n_t^{2}) \quad (4)$$

Thus the receive signal vector can be represented as:

$$r_t = \mathrm{H}_t s_t + n_t \quad (5)$$

4.3.3.2. Space-Time Block Code

The information bits are first modulated using a BPSK modulation scheme. The encoder then takes a block of two modulated symbols s_1 and s_2 in each encoding operation and gives it to transmit antennas according to the code matrix:

$$S = \begin{bmatrix} s_1 & s_2 \\ -s_2 & s_1{*} \end{bmatrix} \quad (6)$$

In the [7], the first row represents the first transmission period and the second row the second transmission period. The first column corresponds to symbols transmitted from the first antenna and the second column corresponds to the symbols transmitted from the second antenna.

The entries of the transmission matrix S are so chosen that they are linear combinations of the modulated symbols $S_1, S_2, S_3, ..., S_k$ and their conjugates $S_1{*}, S_2{*}, S_3{*}, ..., S_k{*}$. The matrix itself is so constructed based on orthogonal designs such that [8]

$$S.S^{H} = c(|s_1|^2 + |s_2|^2 + ... + |s_K|^2)\, I_{M_T} \quad (7)$$

Where c is a constant, M_T is the number of transmit antennas, S^{H} is the Hermitian of S, and I_{M_T} is an $M_T \; x \; M_T$ identity matrix.

At the receiver the signals after passing through the channel can be expressed as,

$$\begin{aligned} r_{11} &= h_{11} S_1 + h_{12} S_2 + n_{11} \quad (8) \\ r_{12} &= -h_{11} S_2 + h_{12} S_1 + n_{12} \\ r_{21} &= h_{21} S_1 + h_{22} S_2 + n_{21} \\ r_{22} &= -h_{21} S_2 + h_{22} S_1 + n_{22} \end{aligned}$$

Where n_{ij} are independent complex variables with zero mean and unit variance, representing additive white Gaussian noise samples at time t and $t+T$, respectively.

4.3.3.3. Codification Process

In order to quantify the benefit that contributes a MIMO channel, it has been simulated two types of codes to codify the message, convolutional codes and LDPC codes.

4.3.3.3.1. Convolutional Codes

The Convolutional code is a type of error correcting code in which k-bit information symbol to be encoded is transformed into an n-bit information symbol.

The first draw of the three points represents the m memory registers. The operation that generates the output bits is modulo-2 sum.

The output bits are:

$$c_1 = \mathrm{mod}\,2(u_1 + u_0)$$
$$c_2 = \mathrm{mod}\,2(u_0 + u_{-1}) \qquad (1)$$

The trellis diagrams generally prefer both the tree and the state diagrams because they represent a linear time sequencing of events. The x-axis is discrete time and all possible states are shown on the y-axis. We move horizontally through the trellis with the passage of time. Each transition means that new bits have arrived.

4.3.3.3.2. Low Density Parity Check

The LDPC codes belong to a special class of linear block codes whose parity check matrix H has a low density of ones. For a LDPC code, its parity check matrix H has elements h_{mn} that are the set of nodes of parity check. Let the code word length be N (the number of symbols), then H is a $M\,x\,N$ matrix, where M is the number of rows. Each row of H introduces one parity check constraint on input data $x = (x_1, x_2, ..., x_N)$:

$$\sum_{n=1}^{N} h_{mn} x_n = 0, \quad for\ m = 1,2,...,M \qquad (9)$$

Putting the m constraints together, we have $Hx^T = 0$. Let function $f_n(x_n)$ be defined as

$$f_n(x_n) = -\ln p(x_n / y_n) \qquad (10)$$

Where $p(x_n / y_n)$ is the conditional distribution of input data symbol n at value x_n given the output data symbol n at value y_n. $f_n(0) - f_n(x_n)$, which is equal to $\ln(p(x_n / y_n) / p(0 / y_n))$, is the log-likelihood ratio (LLR) of input data symbol n at value x_n versus value 0 [9].

4.3.4. Economic Transaction Architecture

The bank transactions can be modelled as a series of server who receive flows of information, this information it is analyzed to realize the transaction to the real addressee. Exist a delay that it is caused by the great quantity of flows that are received and emitting to different entities (clients).

5. Economic Benefit of the New Company

In order to obtain the total Economic Benefit, the following stages have been analyzed. First, it has been elaborated the workflow map of the conversations that participate in the transaction cycle. Then, the conversations were redesigned to improve the efficiency of the process. Second, it has been calculated the number of departures that minimizes the total cost, in order to know the number of transactions that minimizes the cost. Third, it has been calculated the benefit (dB) that a MIMO/LDPC channel reaches with regard to a MIMO and SISO channel that use convolutional codes. Finally, it has been evaluated the impact in a real study case, quantifying the direct (reduction of inefficient conversations), and indirect (reduction in fines because of the process architecture) benefits introduced by the redesign on the conversations.

The figure 9 shows the result of the comparison between the present situation and the future situations and the global benefit is of at least a 20.12%.

5.1.1. Effect of the Conversational Architecture

Without assessing the channel effects, the conversations redesign produces a 14% benefit on the company utilities, considering a decrease in the phone calls costs and a decrease of a 20% in the fines produced by the inefficiency of the actual process. This improvement is necessary to implement the new channel.

5.1.2. Effect of the Channel

It has been compared two channels with convolutional codes for the codification and a BPSK modulation, but with a different number of antennas. It has been supposed an actual system with an antenna on the transmitter and on the receptor. Later, a new system was supposed with two antennas on the transmitter and two on the receptor, simulating the future situation.

To compare the benefits that a MIMO channel can introduce in an organization, it has been compared the benefits at the conversation level [12]. The one antenna systems, to generate a stable conversation, that means a BER efficiency level equal to 1.0E-04, need an approximately 14 dB SNR. The two antennas system needs, on the other hand, just to 6 dB using LDPC codes. This generates an approximate profit of 8 dB, which can reverberate on more services, a reduction of the size of the mobile devices and a higher rapidity on the transactions.

It was also quantified the economic benefit that a MIMO/LDPC channel can produce if it only reduced in an 8% the time of conversation in the processes. The percentage has been calculated under the supposed that a 1 dB reduction produces a 1% benefit in the conversations, even more in the practice because if a signal requests less power to be sent, the message can be understood in less time by the receptor because the information lost before arrives now with a higher brightness.

6. Conclusion

With the transport model it has been calculated the number of departures that minimizes the total cost. This has allowed to estimate the number of optimal transactions, given the actual restrictions. This indicator has been useful as a study parameter to the evaluation of the economic impact of the channel proposed in the investigation.

In order to improve the flows of information inside the organization it has been important to understand that conversations are necessary using the conversational maps. It has been evaluated a redesign in the actual structure of the Conversations, which has generated an economic benefit of 14.84% in the Company.

When the effects of the channel are included in the analysis of the problem they increase the gains because some information would be recovered. The effectiveness of the channel is improved with the new system from 14 dB to 6 dB with a 1.0E-04 BER, giving a benefit in the Company of 5.28%.

If the direct and indirect benefits reported by the redesign of the workflow and the benefit of a MIMO/LDPC channel are summed, it results that the Company has an economic profit of 20.12%.

7. Acknowledgements

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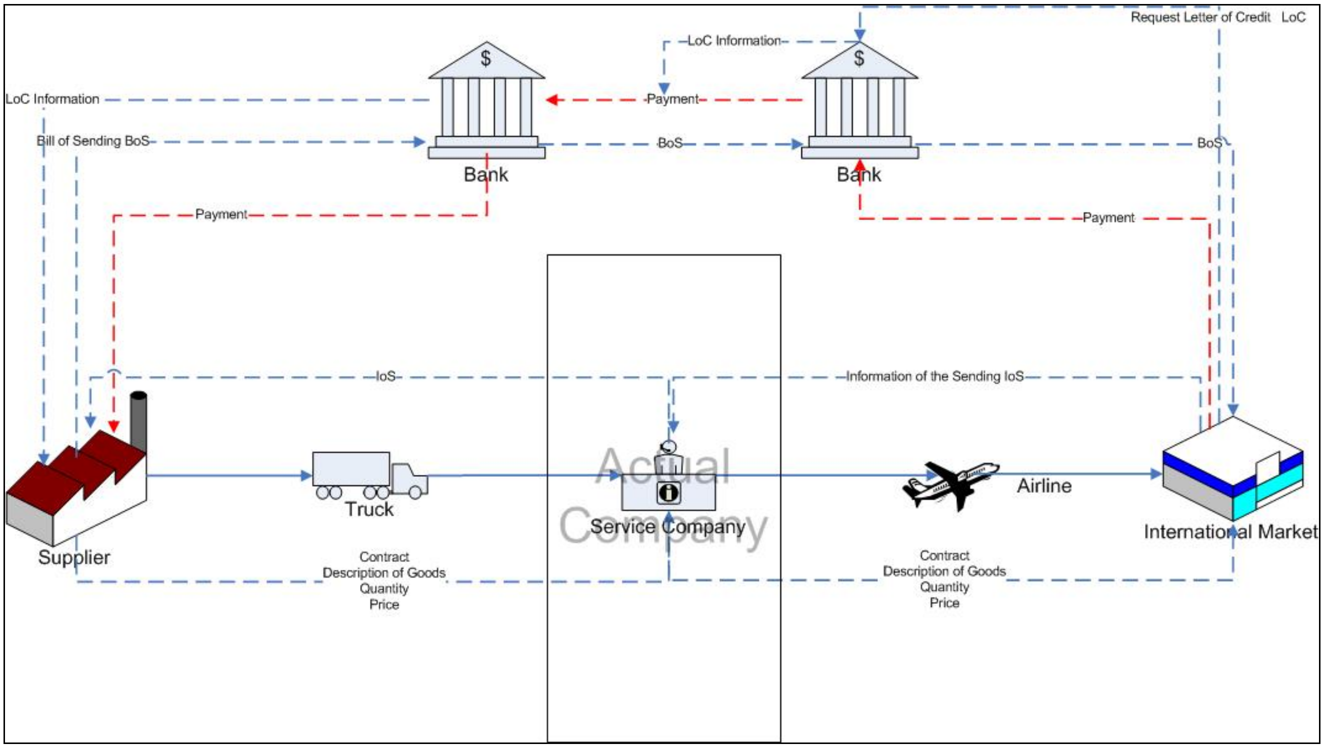

Figure 1 Diagram of the Export /Import Process in the Actual Company.

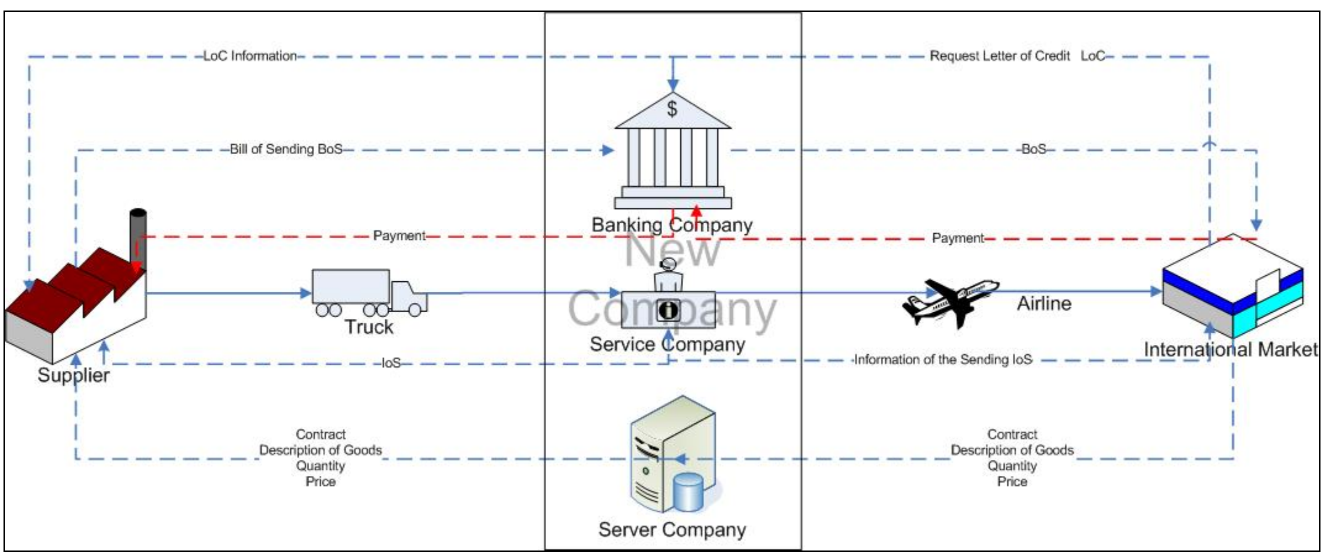

Figure 2 Diagram of the Export /Import Process in the New Company.

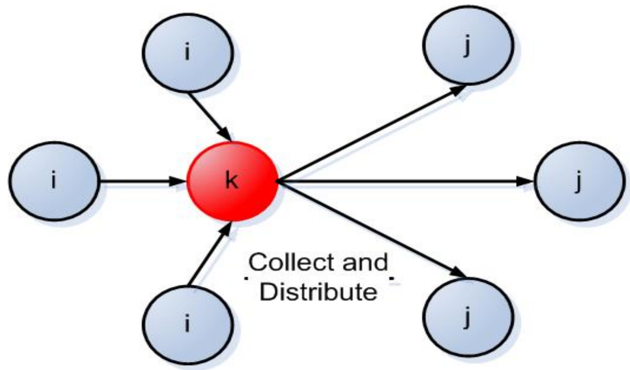

Figura 3 Hub and Spoke Model of the Present Situation.

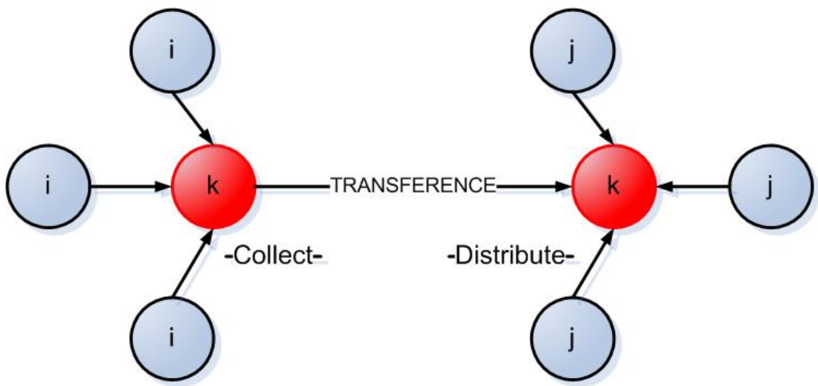

Figure 4 Hub and Spoke Model of the Future Situation.

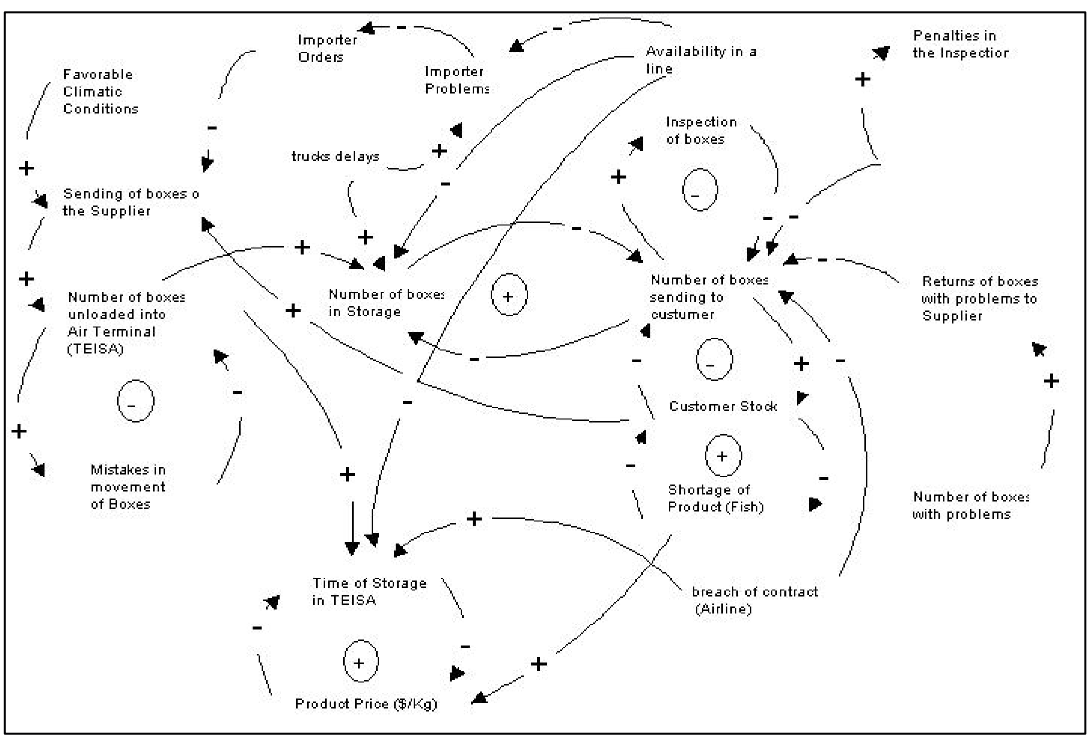

Figure 5 Influence Diagram that represent the principal influence of the System.

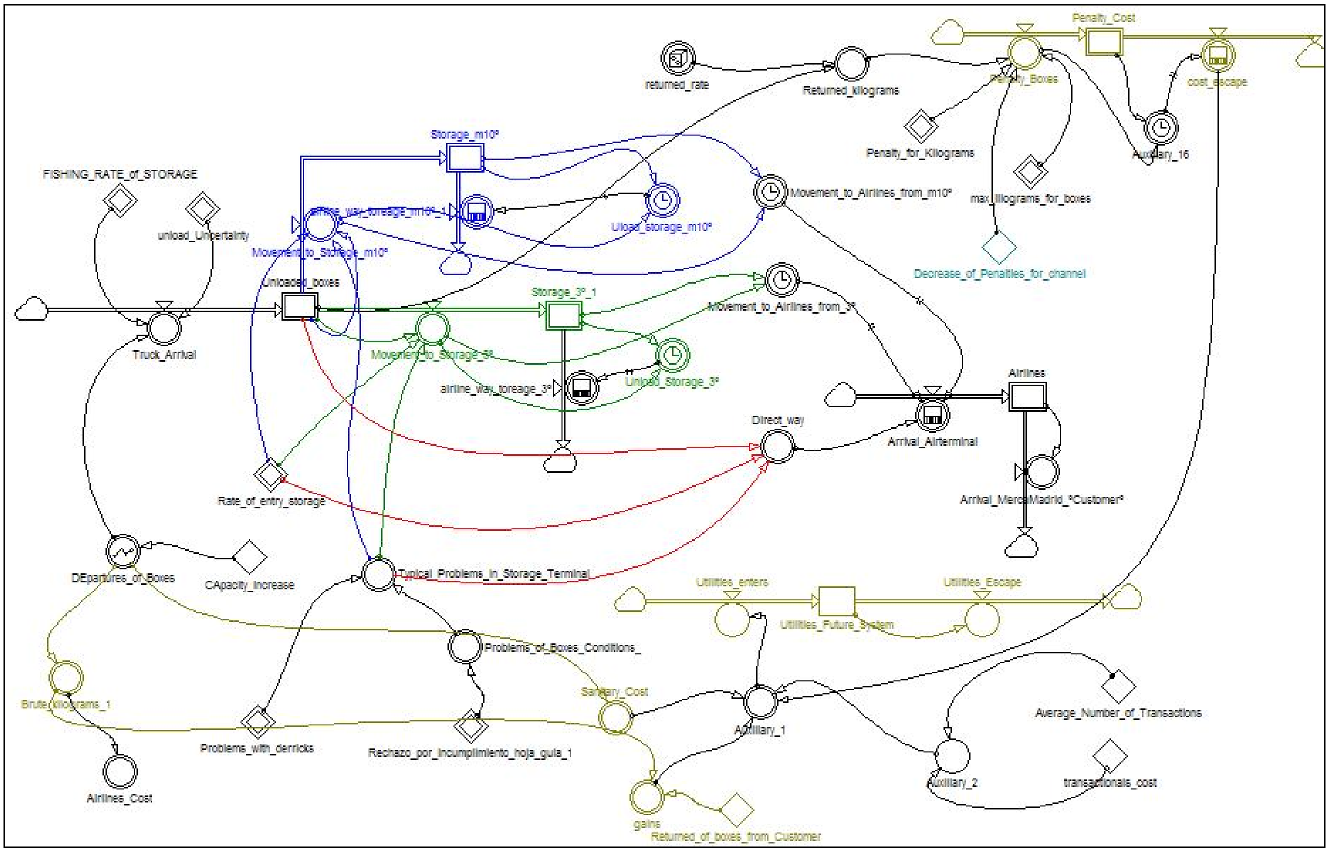

Figure 6 Forrester Diagram of the System, this diagram represents the behaviour of the shipment and it is necessary to simulate the new situation.

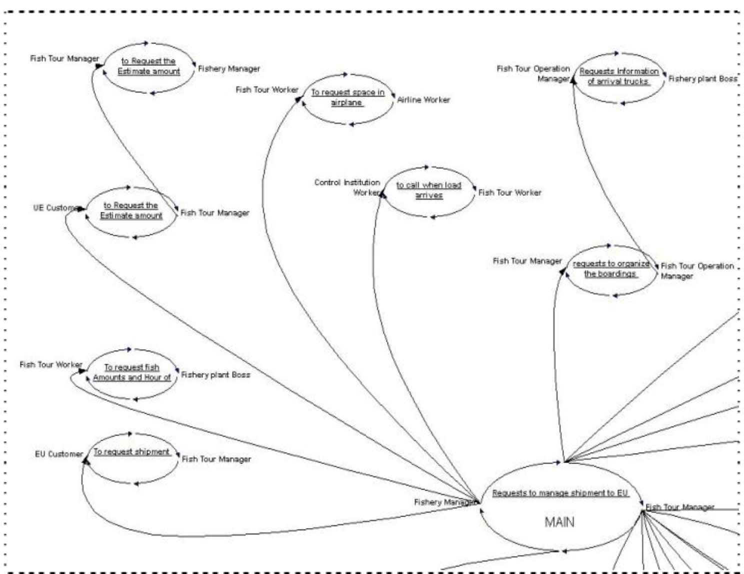

Figure 7 The Conversational map of the Company. Every circle is a conversation generated in the Export/Import process and it represents the commercial cycle.

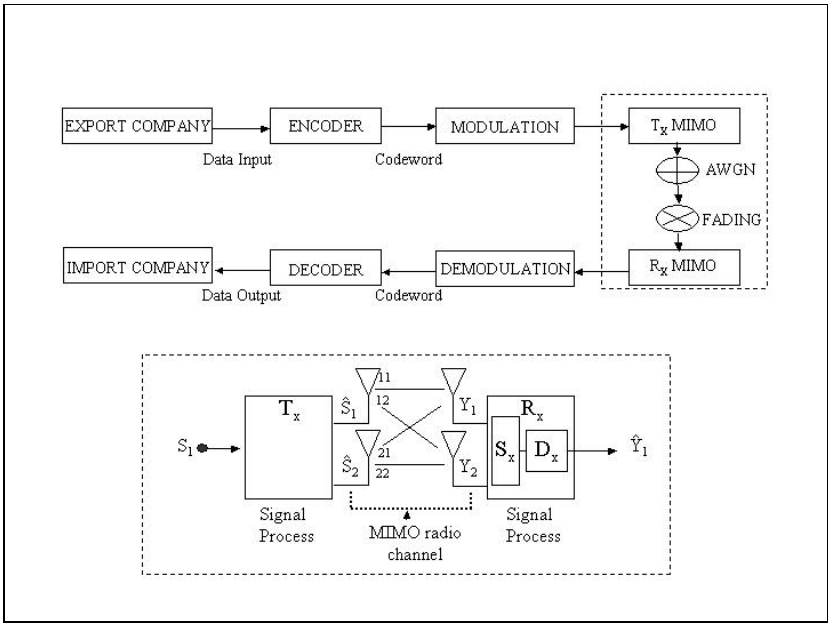

Figure 8 Communication system proposed for the design of the Export/Import process. It is assumed that the MIMO system has two transmitting antennas and two receiving antennas.

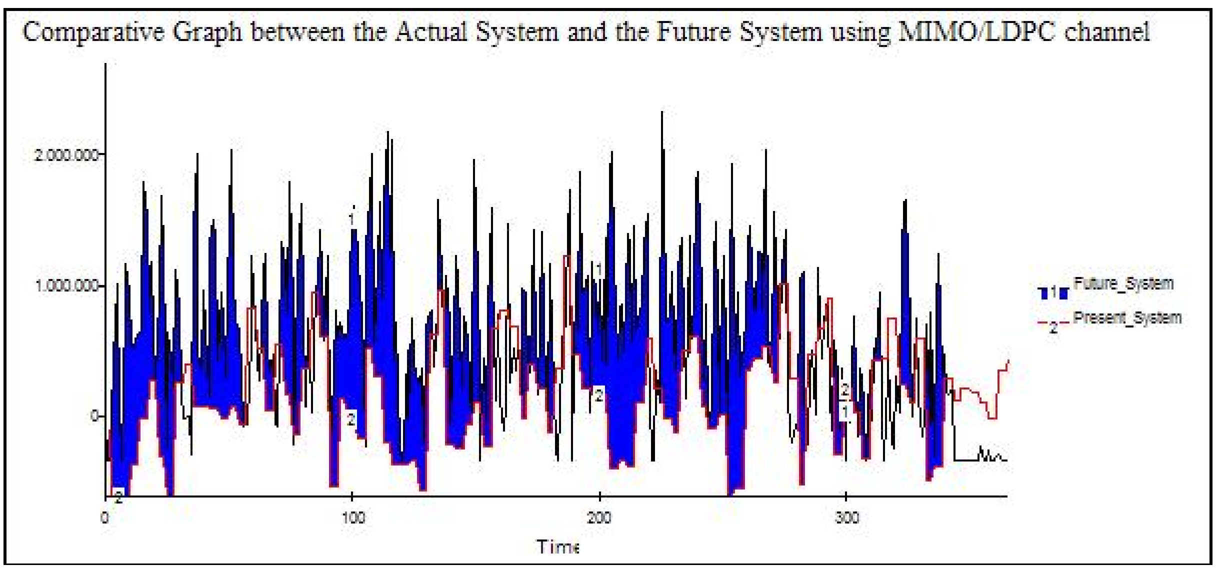

Figure 9 Comparative Graphs between the Present System and the Future System.