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Service Quality Improvement by Application of LP to Modular MIMO Wireless Transaction

Maozhu Jin[1,∗]*, Sheng Zhong*[1]*, Yongzhong Cheng*[2] *and Neson Con*[3]

[1] Business School, Sichuan University, Chengdu 610065, China
[2] West China Hospital, Sichuan University, Chengdu, 610041, P.R. China
[3] School of Electronic Engineering, University of Newcastle, Newcastle, UK

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Abstract: The application of technology in health care service delivery coupled with banking services has been increasingly prevalent as it is effectively employed to reduce patients costs and eliminate uncertainties. The paper investigates the role that technology plays in response time to client enquiries in a health care appointment service supported by banking system and its impact on the delivery of perceived service quality. System Dynamics is used to model information flow and material flow from inside and outside appointment service around the banking in order to identify the principal sources of service delays. A wireless transmission system with Multiple-Input-Multiple-Output structure is proposed and its performance of the data transmission time is evaluated. Based on this, the paper puts forward a linear programming model to optimize transmission cost within the banking office. As a result, the simulation achieves a 27% increases addressed by the number of health care customer inquiries.

Keywords: Service quality, Modular service process, Feedback Loops, Linear Programming, MIMO system, Wireless transaction.

1. Introduction

The marriage between the advanced technology and modern service industry has bought a lot of benefits to the whole China in its process to opening to the outside world and economic restructuring. In this backdorp, this paper investigate the service time and transactions time in a health service appointment system with supportive banking service in order to obtain patient satisfactory performance improvement, knowing that the waiting time in such services contributes great importance to customer satisfaction levels compared to the harder quality improvement that is to related to the reform of health care institution and the banking institution in China. The proposed modifications based on real situation of the existing system of health service delivery with banking support contribute to the constant improvement of patient customer attendance using three effective tools.

The process starts with a customer coming to health care institution to appoint their consulting time and connect to a banks office to address some problems.

Then the working staff of the office sends this information to the main office and this problem is sent to a specialist area to solve it. This very modular processes, however if this informationized transaction takes a lot of time, will proceed very inefficiently. Because as Zuckerman [1] puts forewords a framework to understand this kind of problems which is of great value in banking service systems due to the fact that a great number of problems need be dealt with, this modular service process with various problem solutions will be characterized as NP-hard Problems [2,3].

In recent years, Multiple inputs and multiple outputs (MIMO) system has attracted attention since it can counteract large-scale fading (path loss and shadow fading) and improve coverage, link quality and system capacity. The concept of MIMO system was first proposed by Saleh in 1987 in order to solve the wireless communication coverage in house [4]. Multiple inputs and multiple outputs system using multiple parallel channels transmission method to achieve higher transmission efficiency has become important application area of future communication technique that can yield significant capacity gains over conventional smart antenna arrays to transmit many information with a low bit error rate (BER) in wireless communications [5]. Zheng [6] presents a practical MIMO system operating in

∗ Corresponding author: e-mail: jinmaozhu@scu.edu.cn

a flat-fading environment with low-density parity check where channel state information (CSI) is assumed to be unavailable both to the transmitter and the receiver. In this research, the results show lower decoding complexity and further cause tractable exit functions of the component soft decoders.

This paper is designed to improve the attendant patient customer requests system in health care appointment with banking service support in current situation illustrated by the approach of system dynamics, giving the changes of banking service on the data channel input-output basis for the progress of the information transmission system. Through evaluating the MIMO wireless transactions, a proposed code for this particular application provoking less Bit Error Rate (BER) for a 4G data transmission channel is analyzed to make quick response to the customer requirement in any branches across the country. In this configuration of MIMO system serving banking operation, the original single-objective optimization problem become a typical multi-objective optimization problem and program methods can be applied effectively to solve this problem. These design concepts together contribute a lot to the firm and achieve an improvement of the patient customer service quality.

The paper is organized as follows: Section 2 presents the formulation of the problem and influence diagram is used to demonstrate the system dynamics. Section 3 describes methodology of the response system to customer requirements and LP model proposed to optimize the cost. Section 4 demonstrates the results and finally, the conclusions are given.

2. Problem formulation

The attendant system of customer requests response is consist of a multiple net of 14 areas in which the request is assigned to different areas that give response related to the origin of the request. The characteristics of the system assumes that when a request comes to an area, it is attended and where a different task is waited in this area, it must be realized to be able to emit a response to the customer.

To understand the system complexity, Figure 1 illustrates the general situation using the influence diagrams, which shows inter-influences between the different types of customer requirement entries such as Government, Call-Center, CBRC, SBIF (Agreement with Health care institution), SERNAC (Executive body of strategic alliance) and Personal etc. In this case, the denunciations for problems are caused by the different entries, the transmission time of data within the supportive banking company and between customers and banking company. A high requirement response time is affected positively by number of claims. On the other hand, the improvements of customer service quality decrease the number of claims. The priority caused by the type of entry, such as the government, increased the time of responses to the personal requests. In right cycle

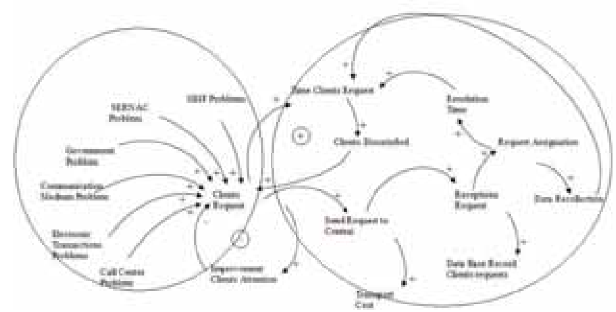

Figure 1 Influence diagram of supportive banking response system

marked the area that must be changed with new infrastructure and there is further explaination in the next section.

The main problem facing the supportive banking company when delivering high quality service is the interval between the arrival time of patient customer request and the time of response to these requirements. Due to reasonable intervention developed for the system, the time of arrival requests can be diminished. The behavior of the customers arrival request can be represented using system dynamics as:

$$\frac{d\,Y(x)}{d\,x} = C_i(x)*(1-Ph(x))*Per_{ij} - C_i(x+Del_\alpha) \quad (1)$$

$$\frac{d\,Pun(x)}{d\,x} = Tex_i(x)*Um_i - Tex_i(x+Del_\beta) \quad (2)$$

Where:

$Y(x)$: Number of patient customer requirements inside of the banking company in week.

$C_i(x)$: Number of patient customer requirements in the tail of customer queue with $i \in [1,6]$, i={Customer C_1, Customer C_2, Customer C_3, Customer C_4, Customer C_5, Customer C_6 }

$Ph(x)$: Probability of the server isnt idle.

Per_{ij}: Percentage of entrance to area of customer with j={CCl, CBRC, Current Client}

Del_α:Delays generated by the permanence of patient customer requirements in the system.

$Pun(x)$:Number of patient customer requirements with response time more than the permitted value (punished requirements).

$Tex_i(x)$:Number of patient customer requirements origin of customer with time of response greater than the permitted, $i \in [1,6]$.

Um:Unitary monetary cost for every customer requirements from customer with response time more than the permitted, $i \in [1,6]$.

Del_β: Information Delay of the punished requirements in the time x.

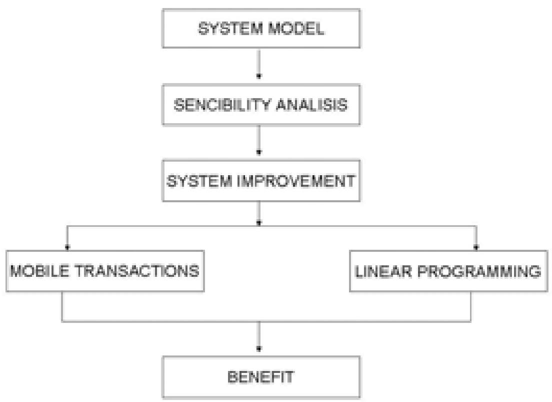

Figure 2 Applied methodology

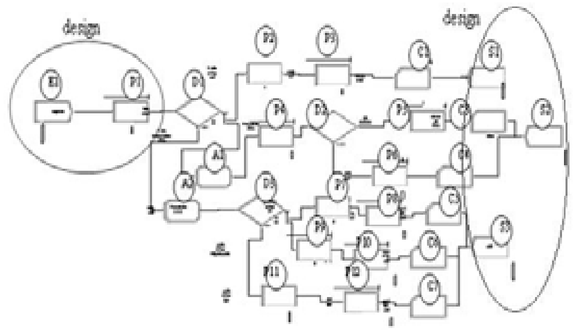

Figure 3 Response system to customers requirements

3. System simulation process and result analysis

At previous stage of problem formulation, the situation has been modeled as a net of systems, where each node is represented as a server which has limited capacity of waiting. Each area has a probability distribution of input/output flows. These probabilities are taken into account in the model. Figure 2 shows the application of the proposed methodology to address the problems, the wireless transactions to improve system performance and the linear programming to optimize the results and makes the comparison finally.

In Figure 3, in the left trapeze symbolizes the entry of customer requirement and the entry channel is same for each customer. The rectangles symbolize the processes, $Pi, i \in [1, 12]$ that must be realized in order to make response from the primary server to the following one. Each process is programmed in agreement with the maximum capacity of attendance and the probability distribution calculated. There in this model exists 12 process. The rhombuses symbolize decisions, $Di, i \in [1, 3]$that are taken in agreement with the characteristics of each request and there in this model exist 3 corresponding decisions. The round vertice square $Ai, i \in [1, 2]$ symbolizes assignment of requirements to corresponding areas. There in this model exist 2 assignments. The trapezes $Ci, i \in [1, 7]$ symbolize the devices that count the requests. There in this model exist 7 counts. Finally the trapezes $Si, i \in [1, 3]$ symbolize storages that are submitting to the customer. There in this model exist 3 storages. The probability distribution of response time is calculated to reflect the response capacity of the system and it shows that the input stage generates a great loss of time for the whole system, due to the fact that all the information is sent in the document to the capital area to be resolved. In red colour is marked the area that can be modified to input of requirements for mobiles devices.

As mentioned above, the bottleneck spot is the most seriously ecological damaged scenic and the most chaotic at a moment, it needs focused monitoring. The longer duration of interference in a bottleneck spot is, the greater degree of threat for the spot will be. The resilience of ecosystems is inversely proportional to the threat level17. Therefore, the key to tourist shunt is to eliminate or distribute bottlenecks. When the bottleneck spot cannot be avoided, reducing the duration of bottleneck can be considered instead, so as to make the spots have sufficient time to achieve self-healing. The principle of DOB evaluation model is to establish joint evaluation model of the duration of bottleneck, and to evaluate the threat level of tourism behavior on the bottleneck spot in different tourist shunt strategies. Obviously, the shorter the duration of the bottleneck, the least ecological damage is to the scenic, and the better the shunt strategy is.

3.1. Linear Programming

In this part we analyze the assignment cost of response in the main supportive office. In order to route the demands between two terminal nodes, the original node delivers all its demands to the hub which it is assigned to. Then this hub forwards them to the destination node which it is assigned to (this step is skipped if both nodes are assigned to the same hub). Finally, the destination node gets the demands from its hub. No direct routing between two terminal nodes is permitted. Two types of costs are counted here: the cost of routing between terminal nodes and transit nodes and the cost of routing between transit nodes. There are often economy of scale for inter-hub traffic problem. we assume that given a set of fixed hubs $H = [1, 2, ..., k]$ described by literature [7] and a set of areas $C = [1, 2, ..., n]$. Direct demand d_{ij} to be routed from area i to area j is given. The distance from area i to hub s is c_{is} which is also called the per unit transmission cost. Similarly we defined c_{st} to be the distance from hub s to hub t. Define $\overrightarrow{x} = \{x_{is} : i \in C, s \in H\}$ x to be the assignment variables. The quadratic formulation is presented by:

$$min\ Z = \sum_{i,j\in C} d_{ij}(\sum{}_{s} \in H c_{ij}x_{ij} + \sum_{j\in H} c_{jt}x_{jt} + \sum_{s,t\in H} \alpha c_{st}x$$

subject to

$$\sum_{j\in H} x_{j,s} = 1\ \forall i \in C,$$
$$x_{i,s} \in \{0,1\}\ \forall i \in C, s \in H$$

All coefficients $d_{ij}, c_{is}, c_{jt}, c_{st} \geq 0$, and $c_{st} = c_{ts}, c_{ss} = 0, \forall i,j \in C, \forall s,t \in H$, α is the discount factor and $0 \leq \alpha \leq 1$Without loss of generality, α can be assumed to be 1. Note that the transmission cost from areas to hubs, $\sum_{i,j\in C} d_{ij}(\sum_{i,j\in C} c_{ij}x_{ij} + \sum_{i\in H} c_{jt}x_{jt})$ is linear on $\overrightarrow{x}$, and it is called the linear cost of the objective function and denoted by $L(\overrightarrow{x})$. Similarly, we call the other part of the objective function the inter-hub cost or quadratic cost, and denoted by $Q(\overrightarrow{x})$. This model can be linearized [8].

$$min\ U = \sum_{i,j\in C}\sum_{s,t\in C} d_{ij}(c_{ij} + c_{jt} + c_{st})$$

Subject to:

$$\sum_{s,t\in H} x_{ijst} = 1,\ \forall i,j \in C,$$

$$\sum_{i\in H} x_{ijst} = x_{i,s},\ \forall i,j \in C, s \in H,$$

$$\sum_{s\in H} x_{ijst} = x_{j,s},\ \forall i,j \in C, t \in H,$$

$$x_{ijst} \geq 0,\ \forall i,j \in C, s,t \in H,$$

$$x_{i,s} \in \{0,1\},\ \forall i \in C, s \in H,$$

Here x_{ijst} is the portion of the data flow from area i to area j through hub s and t sequentially. The formulation involves nonnegative variables and constraints so that enables us to use LP relaxation by replacing the zero-one constraints with non-negative constraints for this particular problem. This kind of LP relaxation is very tight and often generates integer solutions. However, the fact that the size of the LP relaxation is relatively large restricts its applications to large-sized problems. Another problem is to reduce the time complexity, flow formulation for the proposed problem is adapted from a formulation proposed by Ernst and Krishnamoorthy [9]. In this formulation, the route for a pair of areas i and j is not specified. Moreover, this formulation does not need decision variable X_{ijst}. Instead, it is necessary to define $\overrightarrow{Y} = \{Y^i_{st} : i \in C, s,t \in H, s \neq t\}$ where Y^i_{st} is the total amount of the flow originated from city i and routed from hub s to a different hub

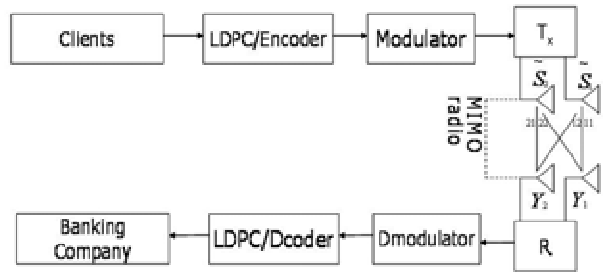

Figure 4 Data MIMO channel

t. Here define $P_i = \sum_{j\in C d_{ij}}$; $D_i = \sum_{j\in C} d_{ji}$ and the problem can be modified and represented by:

$$minW = \sum_{i\in C}\sum_{s\in H} c_{is}(P_i + D_i)x_{i,s} + \sum_{i\in C}\sum_{s,t\in H:s\neq t} c_{st}Y^i_{st}$$

subject to: $\sum_{s,t\in H} x_{ijst} = 1,\ \forall i,j \in C,$

$$\sum_{t\in H:t\neq s} Y^i_{st} - \sum_{t\in H:t\neq s} Y^i_{ts} = P_i x_{i,s} - \sum_{j\in H} d_{ij}x_{j,s}$$

$$x_{i,s} \in \{0,1\},\ \forall i \in C, s \in H$$

$$Y^i_{st}, \quad \forall i,j \in C, t \in H, s \neq t$$

Therefore, this linear model can be applied to this problem, and represent an optimum assignment for every area. Moreover, this is the assignment that minimized the total cost.

3.2. Specific Channel Proposal

Multiple-Input-Multiple-Output channel is proposed to reduce the response time in the entry of the system. Figure 4 shows the data are encoded and modulated so that they can be sent through MIMO channel. For the channel includes a LDPC codes for encoder/decoder process so that the signal must be demodulated and decoded so it can be received in the system.

(1) MIMO system model

Multi-input multi-output (MIMO) system is an important application area of future communication technique. It uses multiple parallel channels transmission method so that it can achieve higher transmission efficiency. After applied the distributed antenna configuration, the original single-objective optimization problem become a typical multi-objective optimization problem because transmitting antennas or receiving antennas located in different geographic locations and using different crystal lead to different transmitting antennas to the same receiving antennas has different frequency offset. It is considered a MIMO system with a transmit array of two antennas and a receive array of two antennas [10]. Even a general Distributed MIMO system that transmitting antenna located in a different location, the mobile service also uses a distributed antenna. At this point, we could consider that the receiving terminals each receiving antenna and the transmitting terminals same transmitting antenna have a different time delay and frequency offset, and also with the transmitting terminals different transmitting antenna. Under such assumptions, there is flat fading between each transmit and receive antenna and memory loss in the channel. The channel matrix at any given time t is given by [11]:

$$H_t = [\begin{matrix} h^t_{1,1} & h^t_{1,2} \\ h^t_{2,1} & h^t_{2,2} \end{matrix}] \quad (3)$$

Where the jith element, denoted by h^t_{ji}, 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^j_t is given by:

$$r^j_t = \sum_{i=1}^{2} h^t_{j,t} s^i_t + n^j_t \quad (4)$$

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

It is represented:

$$r_t = (r^1_t, r^2_t) \quad (5)$$

and

$$n_t = (n^1_t, n^2_t) \quad (6)$$

Thus the receive signal vector can be represented as:

$$r_t = H_t s_t + n_t \quad (7)$$

(2) LDPC Encoder/Decoder Process

The parity check equations in this example have four variable characterizing by the nine functions $f_i\ \forall i \in 1 \leq i \leq 9$where $f_1(x_3, x_6, x_7, x_8)$, $f_2(x_1, x_2, x_5, x_12)$, $f_4(x_2, x_6, x_7, x_10)$ and $f_9(x_2, x_3, x_9, x_10)$ can take value 0 or 1 according to if the equations are or not satisfied. Figure 5. shows these equations represented in H matrix (12,4). Therefore $f_i\ \forall i \in 1 \leq i \leq 9$ are binary functions and we can represent H matrix as: $H = [P^T/I]$. In order to obtain a codified word we applied the following relation: $C = cod|x| = x \bigotimes G$, where C correspond to our codified word.

The generating matrix G can be express like $G = [I/P]$, where I is the identity matrix. For this application the generator matrix characterizing for $(r = 4/12)$, where $(r = k/n)$, the generator matrix G for this code The decoder process begins when the transmitted word is multiplied with the parity check matrix, and if $C \bigotimes H^T = 0$, the transmitted word is ready to decoder, else $C \bigotimes H^T \neq 0$ begins the iterative decoder process. The sum-product algorithm replaces each variable in the constraint graph with a random variable. The task is then to compute the (conditional) probability mass of one variable, given the available independent (conditional) probability masses of all other variables. Each edge in the graph is then associated with four probability masses, because each edge is connected to four nodes.

$$H = \begin{bmatrix} 0&0&1&0&0&1&1&1&0&0&0&0 \\ 1&1&0&0&1&0&0&0&0&0&0&1 \\ 0&0&0&1&0&0&0&0&1&1&1&0 \\ 0&1&0&0&0&1&1&0&0&1&0&0 \\ 1&0&1&0&0&0&0&1&0&0&1&0 \\ 0&0&0&1&1&0&0&0&1&0&0&1 \\ 1&0&0&1&1&0&1&0&0&0&0&0 \\ 0&0&0&0&0&0&1&0&1&0&1&1 \\ 0&1&1&0&0&0&0&0&1&1&0&0 \end{bmatrix}$$

Figure 5 Example of H matrix

Where the initial probability is calculated:

$$P(y) = \frac{1}{1 + e^{\frac{-2y_k}{d^2}}} \quad (8)$$

Message sent by the parity node:

$$\begin{aligned} r^0_k &= (1 + \prod(q^0_k - q^1_k)) \\ r^1_k &= (1 - \prod(q^0_k - q^1_k)) \end{aligned} \quad (9)$$

Using the update factor to calculate the variable message:

$$\begin{aligned} q^0_k &= \alpha_k p^0_j \prod r^0_k \\ q^1_k &= \alpha_k p^1_j \prod r^1_k \end{aligned} \quad (10)$$

Where the update factor is:

$$\alpha_k = \frac{1}{[P^0_j \prod r^0_k] + [P^1_j \prod r^1_k]} \quad (11)$$

Each function node generates, for each edge, a unique estimate of the (conditional) probability mass, based on the information which is presented at the other edges. Probability masses are generally represented by vectors, and may sometimes be represented by summary messages, such as log-likelihood ratios or soft bits.

$$L(x_i/y) = \ln \frac{p(x_i = 1/y)}{p(xi = 0/y)} \quad (12)$$

4. Result and discussion

Our work aim to create a new process to data input service and therefore bring the service capacity increases of " the bottleneck". Considering this, the balance between the efficiency measurements: units and time of service inside the supportive company versus server amplification

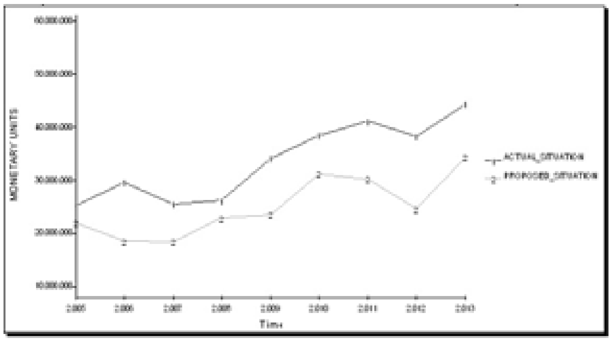

Figure 6 Costs comparison

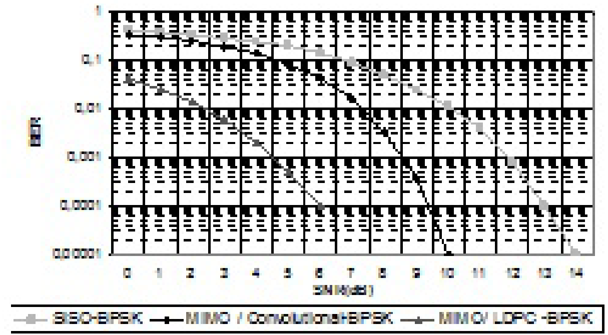

Figure 7 Comparison between SISO and MIMO channel

capacity costs becomes the evaluation meaurement of our proposed method.

We used the flow of the actual requests of the system as model input and evaluated a plan of short-term improvement. The resulted gains expressed as the decrease of penalties due to delay imposed by CBRC and SERNAC according to SBIF force the Bank Company to improve the corporate image, increase customer loyalty and decrease the operation costs. Figure 6 shows the cost comparison between in the actual situation and in the proposed situation. This simulation includes the channel effect and the optimization of the assignment problem.

Figure 7 shows the performance comparison of BPSK modulation process among SISO (Single Input-Single Output), proposed MIMO (Multiple Input-Multiple Output) channel with Convolutional and LDCP for Encoder / Decoder respectively. The SISO channel, to generate a stable conversation, that indicates a BER efficiency level equal to 1,0E-04, needs an approximately 14dB SNR. The MIMO / Convolutional just needs 9dB SNR. This generates an approximate profit of 5 dB SNR and MIMO/LDPC only needs 6 dB SNR. The profit that a MIMO channel can bring in the supportive banking company can reverberate on more electronic services, and a higher speed on the transactions.

5. Conclusion

The proposed methodology to solve problems contains conceptualization and modelling of the actual situation and application of optimization techniques to the sensitive areas of health care service delivery system with banking service support. This methodology has helped to determine new system problem and improve customer service quality. The particular assignment problem was fomulated by LP and solved to minimize the cost of response in the main office, giving a feasible solution. In the comparison of the use of a mobile wireless communication to transmit the data from the health care service customer to the supportive banking company and from the suportive banking company to the customer, the computer simulation supposes that the current situation can be represented by a wireless communication SISO and the proposed methodoly for a MIMO. The benefit brought by the utilization of MIMO channel is equivalent to 5dB for 1,0E-04 BER using Convolutional codes and 8dB for 1,0E-04 BER using LDPC codes. Moreover this paper shows the importance of the code in the data transmission.

With these combined changes, the computer simulation shows an performance improvement of 34% by the customer service quality. The proposed modifications support the extention plan of the connection between the health care instituaiton and banking institution, the sustainable improvement of customer attendance and strategic market competitiveness. Finally, the proposed system and methodology sheds the light to the similar transaction requirement systems and an new infrastructure buildup to more efficient communications and customer service quality.

Acknowledgement

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References

[1] O. Zuckerman and M. Resnick. System Blocks: A Physical Interface for System Dynamics Learning. MIT Media Laboratory, USA(2003).
[2] P. N. Klein and N. E. Young, Approximation Algorithms for NP-Hard Optimization Problems, in Algorithms and Theory of Computation Handbook, ed. M.J. Atallah, CRC Press, ch. 34, 1-19 (2010).
[3] S. A. Rustako, R. Roman. Distributed Antennas for Indoor Radio Communication. IEEE Trans. Commun, Dec. 35, 1245-1251 (1987).

[4] J. Feldman. Decoding Error-Correcting Codes via Linear Programming. PhD thesis, Massachusetts Institute of Technology (2003).
[5] D. E. Hocevar. A reduced complexity decoder architecture-via layered decoding of LDPC codes. In Proceedings of the IEEE Workshop on Signal Processing Systems, USA (2004).
[6] S Alumur, B Kara. Network hub location problems: the state of the art. Eur J Oper Res, 190, 1-21, (2008).
[7] J F Campbell, A T Ernst, M Krishnamoorthy. Hub arc location problems: introduction and resultsManagement Science, 51, 1540-1555 (2005).
[8] A T Ernst, M Krishnamoorthy. Solution Algorithms for the Capacitated Single Allocation Hub Location Problem. Annals of Operations Research, 86, 141-159 (1999).
[9] X Lei, Maozhu Jin. Application of Bayesian Decision Theory Based on Prior Information in the Multi-Objective Optimization Problem
[10] Z Chen, J Yuan, and B. Vucetic, Analysis of transmit antenna selection/maximal-ratio combining in Rayleigh fading channels, IEEE Trans. Veh. Technol. 54, 1312-1321 (2005).
[11] V Tarokh, et al. Space Time Codes for High Data Rate Wireless Communication: Performance Criteria in the Presence of Channel Estimation Error. IEEE Trans. Commun. 47, 199-207 (2007).