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Development of A Model for Bank Cash Deposit Transactions Using Hierarchical Timed Coloured Petri Nets

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ABSTRACT: Significant investments are being made yearly to improve service quality and delivery in banking systems to minimize customers' dissatisfactions with long waiting time due to overcrowding. However, to address this problem, most existing empirical studies are limited only to cash deposit transaction modelling for deposit slip mode of cash payment. This paper developed a model for bank cash deposit transactions involving both Deposit Slip (DS) and Point of Sale (POS) using Hierarchical Timed Coloured Petri Nets (HCPN). The Primary data required for model development in this study were acquired from a reputable bank in Nigeria. The data were statistically analyzed using EasyFit Simulation software to determine the model parameters (the distribution of the inter-arrival times of customers entering the banking hall for DS and POS services and the distribution of the service times for servers). These parameters were then used as inputs in developing the HTCPN model which consists of two modules named Environment and Banking-Hall. The Environment module was used to model the arrival of POS customers while the Banking-Hall module was used to model the arrival of customers aiming to deposit cash in banking hall via DS. Thus, through the Environment and Banking-Hall modules, the model could be easily modified and employed to experiment DS and POS modes of cash payments in banking systems.

Keywords: Point of Sale, Deposit Slip, Hierarchical Timed Coloured Petri Nets, EasyFit Software

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I. INTRODUCTION

Customers' satisfaction is generally enhanced through improved service delivery and this has been identified as a major contributing factor to achieving business success. In any service organization, the time that the customers are required to wait to receive service is always of great concern to the management of such organization. For instance, service quality and delivery are taken to be the core competence of banks to which special attention is always given. This is important because the banking sector is the core component of the financial system of any country that provides various financial services to support capital markets, insurance and asset management in terms of payment services, intermediation between savers and borrowers; and insurance against risk.

The queue length and waiting time are two matrices of banking service efficiency. Therefore, effective and efficient utilization of facilities in a manner that will satisfy all stakeholders is always the utmost priority of bank management. However, achieving this feat had been a challenge to the banking industry for many years. This is again aggravated by the increased patronage of banking services by more people due to the awareness and desire for more reliable mode of financial management. Despite this challenge in the banking system, the quest to reduce operating cost has resulted in banks engaging minimal staff strength that are expected to attend to all the customers effectively and satisfactorily. However, this has resulted to poor service delivery and delay in service response culminating in customers waiting for a long time on the queue. In solving this problem, there is a need for the application of different systematic approaches which are useful in evaluating alternative service configurations. Among the various approaches available for evaluating different alternatives, simulation technique such as Coloured Petri Nets has high capability for modelling and evaluation of the system's performance. Colored Petri Nets (CPNs) extend the classical Petri net formalism with data, time, and hierarchy. These extensions make it possible to model complex processes as CPNs without being forced to abstract from relevant aspects (Van der Aalst *et al.*, 2013). When time concepts are introduced into a Coloured Petri Net model, a Timed Coloured Petri Net (TCPN) model is obtained (Ganiyu *et al*., 2011a). Thus, with a Hierarchical Timed Coloured Petri Net, it is possible to predict performance measures, such as the time at which a customer arrives and receives service, average flow time and percentage of customers being attended to.

A number of studies have been carried out on shortening the queueing time in banks. For example, Ramaswamy and Banavar (2008) proposed a model for service delivery system that is based on concepts of service operating system that manages the processes and resources within a service delivery system. This work is a good starting point but cannot be used for building a differentiated QoS based service delivery system. Chafle *et al.* (2009) suggested a generalized optimization model and framework for delivering differentiated QoS. However, the model has accurately helped the organization to realign their focus around important customers and services by segmenting its customers as well as services to make it attractive for important customers and customers coming for revenue generating transactions (like fund transfers). Sameep *et al*. (2011) suggested a solution to the problem by increasing the service personnel at the branch and have dedicated counters for different types of transactions or services. However, this would lead to a substantial increase in the operating cost of the bank which makes it an undesirable alternative.

Also, Dhillon *et al.* (2009) simulated the effectiveness of specialized teller for deposit transactions (customers making deposits were segregated from all others) on customer wait times in the system. However, this does not yield the desire result because the model focused more on customers using deposit slip to deposit money only and overlook the customers that are using POS to deposit money. Several efforts have been made for shortening the queuing length and waiting time as earlier highlighted. In all of these efforts, there were no reports of POS mode of depositing cash. Rather, emphases were made on only one mode of depositing cash in the banking hall which is Deposit Slip mode. Hence, in this paper, Hierarchical Timed Coloured Petri Nets (HTCPN) formalism is explored to develop a model for Bank Cash Deposit Transactions involving both Deposit Slip (POS) and Point of Sale (POS) modes of cash payments.

II. METHODOLOGY

In this paper, the following basic definitions of Coloured Petri Nets (CPN) and Timed Coloured Petri Nets (TCPN) were employed in developing a Hierarchical Timed Coloured Petri Nets (HTCPN) model for bank cash deposit transactions:

A Coloured Petri Nets is a tuple CPN = (Σ , P, T, A, N, C, G, E, I) where:

(i) Σ is a finite set of non-empty types, also called colour sets.

(ii) P is a finite set of places.

(iii) T is a finite set of transitions.

(iv) A is a finite set of arcs such that: $P \cap T = P \cap A = T \cap A = \emptyset$.

(v) N is a node function. It is defined from A into $PxT \cup TxP$.

(vi) C is a colour function. It is defined from P into Σ .

(vii) G is a guard function. It is defined from T into expressions such that:

$\forall t \in T :$[Type (G (t)) =B ∧ Type(Var(G(t))) $\subseteq \Sigma$].

(viii) E is an arc expression function. It is defined from A into expressions such that:

$\forall a \in A:$ [Type(E(a)) = $C(p)_{MS}$ ∧ Type(Var(E(a))) $\subseteq \Sigma$] where p is the place of N(a).

(ix) I is an initialization function. It is defined from P into closed expressions such that: $\forall p \in P :$ [Type(I(p)) = $C(p)_{MS}$].

A timed non-hierarchical Coloured Petri Nets is a tuple TCPN = (CPN, R, r_o) such that:

(i) CPN satisfies the above definition.

(ii) R is a set of time values, also called *time stamps.* It is closed under + and including 0.

(iii) r_o is an element of R called the *start time* (Huang and Chung, 2011; Ganiyu *et al*., 2011a; Ganiyu *et al*., 2011b).

The basic idea behind hierarchical CPNs is to allow the modellers to construct a large model utilizing a number of small CPNs. This is similar to the situation in which a programmer constructs a large program by using a set of modules. In a hierarchical CPN, it is possible to relate a transition to a separate CPN, providing a more precise and detailed description of the activities represented by the transition. The hierarchical CPN definitions are analogous to the non-hierarchical CPNs (Huang and Chung, 2011).

1.1 Description of the Case Study

The cash deposit transactions characterizing one of reputable Guaranty Trust Bank (GTB) branches in Nigeria were used as case study in the model development. The branch uses two modes of depositing money, which include Point of Sale (POS) and Deposit Slip (DS). Figure 1 shows the flowchart of bank cash deposit transactions in the considered GTB branch. The bank utilizes three tellers in the banking hall attending to customers paying through DS and there is a dedicated Automated Teller Machine (ATM) machine in the bank environment for customers paying through POS.

1.2 Data Collection

In this study, primary data were collected on two modes of depositing cash (DS and POS) characterizing the GTB branch under consideration. Data collected include customers' number (N), Inter Arrival Time (IAT) and Service Time (ST) from Monday to Friday between the hours of 8:00 am and 4:00 pm for a week. These data were analyzed statistically using the EasyFit Simulation software to determine the model parameters (the distribution of the inter-arrival times of customers entering the banking hall for DS and POS services and the distribution of the service times for servers). These parameters were used as inputs into developing HTCPN model which consists of two modules (outside the banking hall for POS and within the banking hall for DS).

2.3 The Development of HTCPN Model for the Bank Cash Deposit Transactions

The HTCPN model of the bank cash deposit transactions under consideration was developed consists of two modules: The *Environment* and the *Banking Hall*. Each module was represented in the top page by a special transition called substitution transitions. The Top page captured the most abstract representation of the cash deposit in the banking system. Tables 1 and 2 show the description of the major places and transitions that were employed in the development of hierarchical TCPN model of the bank cash deposit transaction which represent the conditions and events or activities of the system under consideration respectively. The screenshot of CPN tools displaying the Bank Cash Deposit Transaction Model (top page) of the developed HTCPN model is shown in Figure 2. The left of the screen is called index while the right side of the screen is called workspace. The index includes the tool box which contains sets of tool palettes that were used in creating, manipulating the declarations and cloning of the basic elements of the developed HTCPN model. Index also shows the history of the developed HTCPN model by listing the operations that were performed on the model. The name of the model, declaration of the colour sets, variables and constants were all contained in the index part of the screen. The workspace contains a binder (a rectangular window) where all the CPN nodes were drawn.

Table 1: Description of Major Places of the Developed HTCPN Model

Place	Description
NextcustomerID	This place models arrival of customer into the banking environment and the type of customer
POS Rate	This place was used to generate arrival time of customer using Point of Sale mode of transaction in the banking environment.
Teller Rate	This place was used to generate arrival time of customer using deposit slip mode of transaction in the banking hall.
Freeteller	This place models number of tellers in the bank
Queue	This place models the list of deposit slip customers waiting for service in the banking hall.
DoneS	This place models number of customers served
DoneR	This place models number of customers rejected.

Table 2: Description of Major Transitions of the Developed HTCPN Model

Transition	Action
POS Arrive	Execution of this transition models arrival of customer using Point-of-Sale mode of transaction.
TELLER Arrive	Execution of this transition models arrival of customer using deposit slip for transaction.
DSStart Serve	Execution of this transition models service Operation of tellers.
Start POS Service	Execution of this transition models service Operation of POS machine.
End POS Service	Execution of this transition models end of service Operation of POS machine.
End Serve	Execution of this transition models end of service Operation of tellers.

2.3.1 The environment module of the developed HTCPN model

The “*Environment*” module was used to model the arrival of POS customers. The module has six (6) places and four (4) transitions, which include: POS Rate, NextPOSCustomerID, POSQUEUE, POSMachineFree, POS_CUS in Service, Served POS_CUS, POS ARRIVE, StartPOSService, EndPOSServe, and measure served POS_CUS respectively. The states of the system were represented by means of places (drawn as ellipses or circles). The names of the places were written inside the ellipses. The actions in the system were represented by means of transition, drawn as rectangles. Arcs were used to connect transitions to places and vice versa. The arc joining places to transitions indicated incoming arcs in which transition removes token form the corresponding place while the arc coming from transitions to places indicated the output arc. The numbers of tokens that can be removed or added to places were determined by the arc expressions which were positioned next to the arcs. The use of variables in arc expression means that each transition can occur differently. A token on the place ‘NextPOSCustomerID’ determines when new customer arrives. The color set for the place is a timed color set and the time stamp of the token on the place determines when the Next transition can occur. There is no token on the place in the initial marking. The inscriptions ‘cn and cn+1’ on the arc from the place ‘NextPOSCustomerID’ to the transition ‘POS Arrives’ were used to generate the addition of customer to the queue and checking the arrival of new customer.

The arc inscription ‘()@++monPIAT()’ was used to determine the rate at which customers that are using POS to deposit cash were coming into the bank premises. This time stamp was used to ensure that the first customer will not always arrive at time zero for different simulations. The transition ‘POS Arrive’ will occur only when the time stamp of the token on the places ‘POS Rate’ is equal to their corresponding time on the inscriptions. When the transition occurs, a new customer enters and bound to the variable ‘customer’ via the code segment of the transition. The arc inscription “cs^^[({CustNo = cn, CustID = POS_CUS, Atime = ATIMES(), Tsr = modelTime(), Tss = modelTimeS(), Wt = 0.0, St = 0.0})]” on the arc to place ‘POSQueue’ was used to determine the time at which the customer using POS joins the queue. The time inscription of “StartPOSService” randomly draws value from Uniform distribution with discrete boundary parameters “1, 6”;

"1, 4" and "1, 5" on Monday, Tuesday and Wednesday for POS. The arc expression **'**(c, POS)**'** on the input arc of "EndPOSserve" means a pair of customer and a POS machine, this is depicted in Figure 3.

2.3.2 The banking hall module of the developed HTCPN model

The *'Banking Hall'* module was used to model the arrival of customers that want to use DS to deposit cash into the banking hall. Figure 4 shows the banking hall module of the developed HTCPN model of bank cash deposit transaction. The module has six (6) places and four (4) transitions, which include: TELLER Rate, NextTellerCustomerID, QUEUE, Freeteller, Busy, Served TELLER_CUS, TELLER ARRIVE, DSStartServe, EndServe, and measure served TELLER_CUS respectively. A token on the place 'NextTellercustomerID' determines when new customer arrives. The color set for the place is a timed color set and the time stamp of the token on the place determines when the Next transition can occur. There is no token on the place in the initial marking. The inscriptions **'**cn and cn+1' on the arc from the place 'NextTellercustomerID' to the transition 'TELLER Arrives' were used to generate the addition of customer to the queue and checking the arrival of new customer. The arc inscription '()@++monTIAT()' was used to determine the rate at which customers that are using Deposit Slip to deposit cash were coming into the banking hall. This time stamp was used to ensure that the first customer will not always arrive at time zero for different simulations. The transition 'TELLER ARRIVE' will occur only when the time stamp of the token on the places 'Teller rate' is equal to their corresponding time on the inscriptions. When the transition occurs, a new customer enters and bound to the variable 'customer' via the code segment of the transition. The arc inscription "cs^^[({CustNo = cn, CustID = TELLER_CUS, Atime = ATIMES(), Tsr = modelTime(), Tss = modelTimeS(), Wt = 0.0, St = 0.0})]" on the arc to place 'Queue' was used to determine the time at which the customer using Deposit Slip joins the queue.

The serving of customers was modelled as two transitions, "DSStartService" and "Endserve". This was to indicate that the action of service is not instantaneous. Time was introduced by assuming the global clock representing the current model time. Time stamp was assigned to each tokens, indicating when the token can be consumed. The consumption of the token can only take place if its time stamp is less than or equal to the current model time. A token with a time stamp in the future as compared to the current model time can be reqarded as a promise that at some point in the future, a token will be produced. The inscription on the place freeteller, "Teller.all()@++10.0" indicated the three tellers were available at time 10. On place "freeteller", an initial marking of 1'teller(1)@10.0+++1'teller(2)@10.0+++1'teller(3)@10.0 was added specifying that the initially, teller(1), teller(2) and teller(3) were free for use. In order to join the tokens, **'+++'** was used. Place "queue" has initial marking 1'[] , indicating that the place contains a single token, an empty list. Also, the expression 'c::cs' on the input arc of transition "DSstartservice" assigns the head of the list to c and the tail to cs. A transition "DSstartservice" is only enabled when the list on the corresponding input place contains at least one element. The time inscription of "DSstartservice" randomly draws a value from Poisson distribution with a mean of 2.18 on Monday, Uniform distribution with discrete boundary parameters 0 and 5 on Tuesday, Poisson distribution with a mean of 2.66 on Wednesday, Uniform distribution with discrete boundary parameters 0 and 4 on Thursday and Binomial distribution with 48 number of trials and the continuous success probability value of 0.96 on Friday for teller. Places "DoneS" and "DoneR" are of type 'Out'. The color set CUSTOMERxTELLER is a product color set that represents the period when a teller was busy attending to a customer. The arc expression '(c,tl)' on the input arc of "Endserve" means a pair of customer and a teller

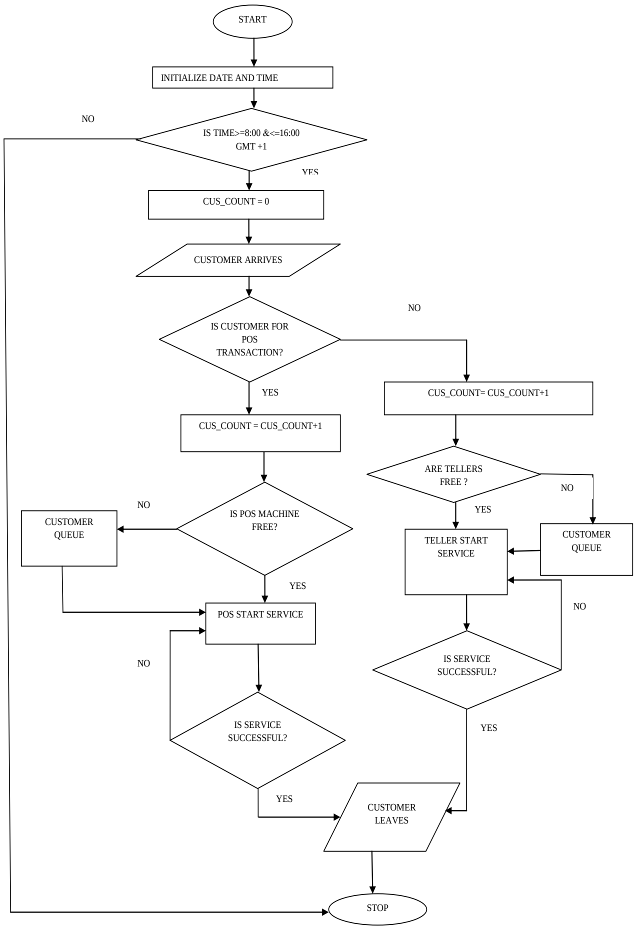

Figure 1: The flowchart of cash deposit transactions in the considered GTB branch

2.3.3 The Assumption made in the Developed HTCPN Model

In developing the Hierarchical Timed Coloured Petri Nets (HTCPN) model for the Cash Deposit Transactions in banking system under consideration, the following assumptions were made:

(i) One time stamp unit represents one minute in the HTCPN model.
(ii) The customers arrive at the banking premises randomly.
(iii) The bank opens for 480minutes per day (60*8hours).
(iv) In the banking hall, servers are in parallel (all servers provide the same type of service and a customer need only pass through one server to complete service).
(v) First Come First Serve (FCFS) queue discipline was adopted.

III. CONCLUSION AND FUTURE WORK

In this paper, we have been able to develop a Hierarchical Timed Coloured Petri Net (HTCPN) model for bank cash deposit transactions using one of reputable Guaranty Trust Bank (GTB) branches in Nigeria as a case study. The developed model can be easily modified through its associated modules to suit any future modifications. Also, it can be experimented to gain insights into overcrowding problems associated with the bank cash deposit transactions under consideration. It is recommended that future research may be geared towards validating and analyzing the performance of the developed model through simulation based analysis technique.

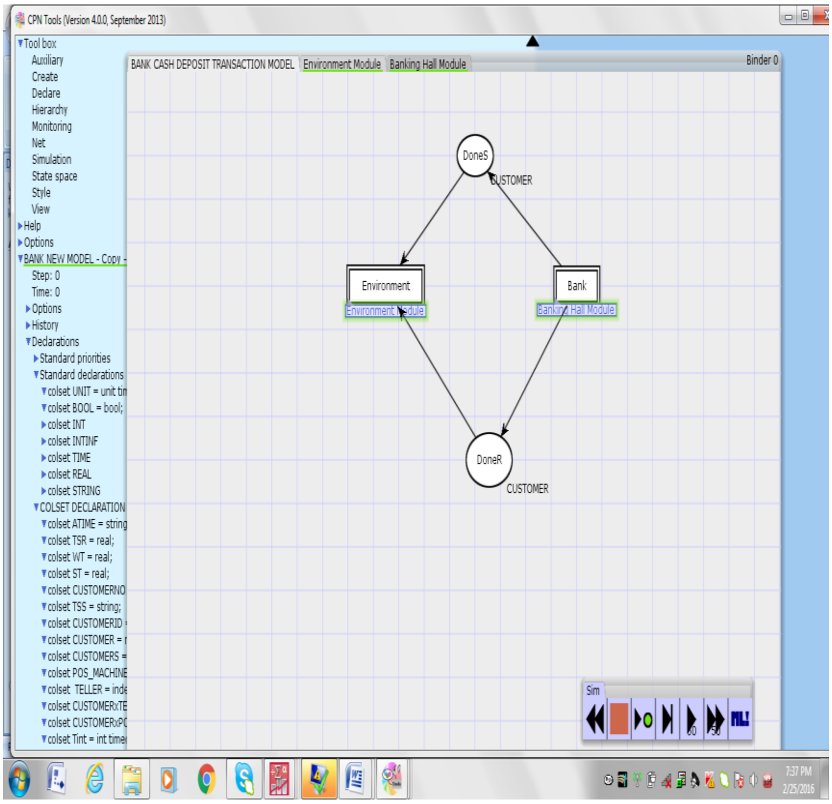

Figure 2: The Developed HTCPN Model for Bank Cash Deposit Transactions

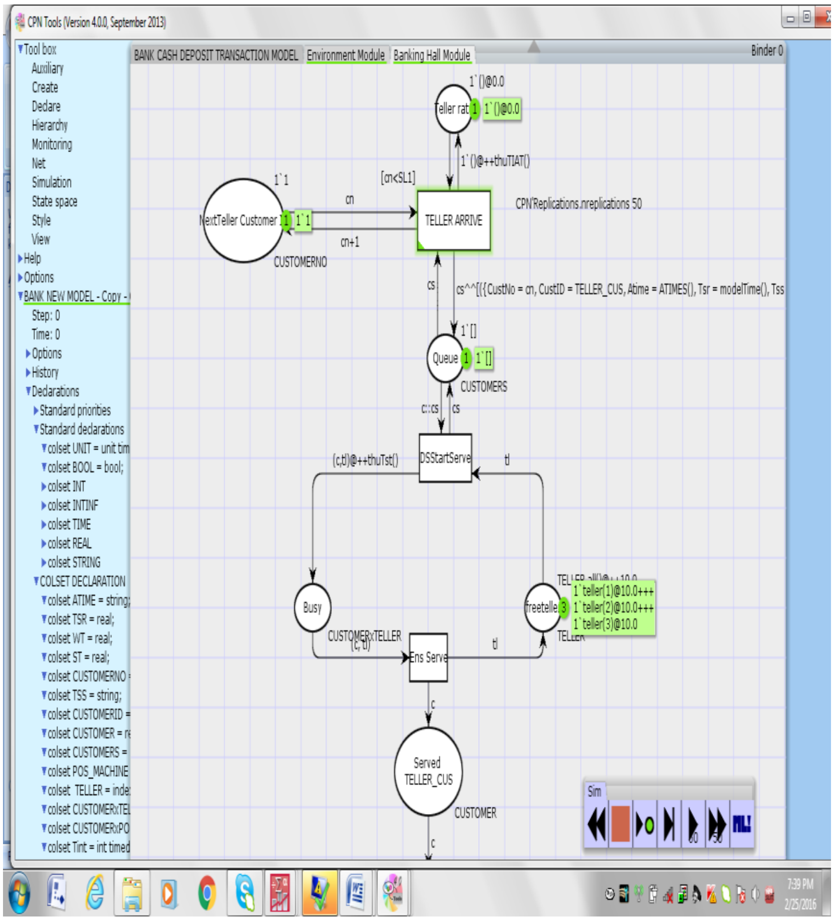

Figure 3: The Environment module of the Developed HTCPN Model

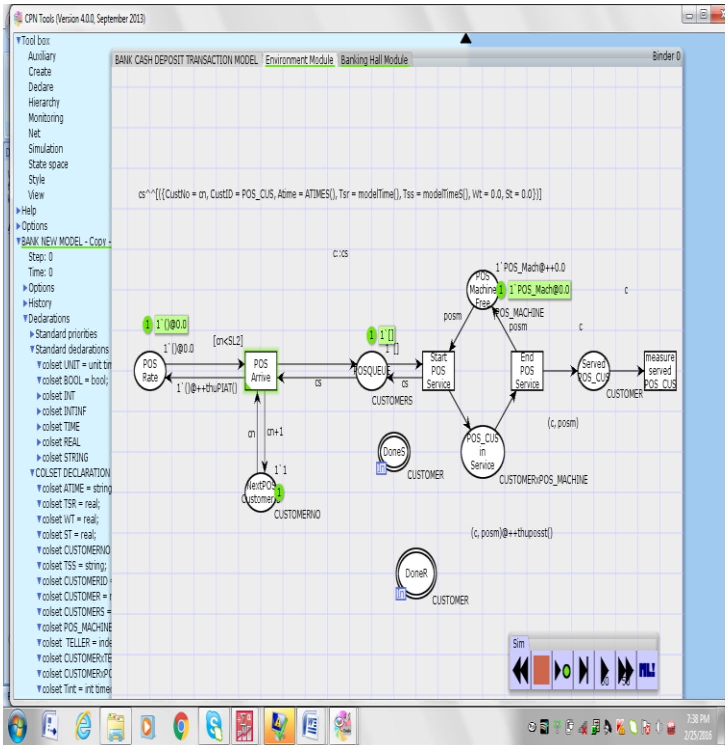

Figure 4: The Banking Hall module of the Developed HTCPN Model

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