International Journal on Recent and Innovation Trends in Computing and Communication ISSN: 2321-8169
Volume: 5 Issue: 7 858 – 864

Petri Net Based Reliable Work Flow Framework for Nephrology Unit in Hospital Environment

P.T.V. Bhuvaneswari[1]
[1]Department of Electronics Engineering, MIT Campus
Anna University, Chennai, India
ptvbmit@annauniv.edu

M. Amaliya Princy[2]
[2]Verizon Data Services India Pvt. Ltd
Chennai, India
princysugu@gmail.com

Abstract— The 21st century has witnessed a revolution in Biology and Medicine that has radically changed the way health, diagnosis, prognosis, etc., of a disease is monitored nowadays. Accordingly, hospital redesign, workforce planning and scheduling, patient flow, performance management, disease monitoring, and health care technology assessment need to be modeled efficiently. Mathematical modeling and computer simulation techniques have been shown to be increasingly valuable in providing useful information to aid planning and management. Petri Net (PN) is considered as a powerful model since it combines well-defined mathematical theory with a graphical representation which reflects the dynamic behavior of systems of interest. Due to dynamic characteristics, it is found to be more suitable for modeling Hospital Management System (HMS). In this paper, a Petri net model-based reliable workflow framework for Nephrology unit in hospital environment is proposed to track the movement of patients in the unit. The key objective of the proposed reliable workflow framework is to provide a well-organized health care unit to reduce the waiting time of the resource/ patient. The performance of the proposed Petri net model-based reliable workflow framework is simulated and validated through reachability graph using HPSim tool. The proposed Petri net workflow framework for the Nephrology unit can be used to deliver highly efficient and reliable healthcare services.

Keywords- *Hospital redesign, Petri net, Nephrology, Reliable, Workflow and Waiting time.*

*****

I. INTRODUCTION

The growth of automation, which is largely linked to advancements in microelectronics, has led to significant improvement in reliable and cost-effective productions [1]. Hospital automation is a subarea of automation, which aims to automate processes in the hospital environment. The efficiency and productivity of the process can be increased by using industrial automation concepts. However, selection of these concepts depends on the characteristics and restrictions of the medical environment. For example, data acquisition must ensure privacy in preserving medical ethics and patient integrity [2].

Hospital Information System (HIS) contains three different modules, namely Patient record, Resource record and Infrastructure record. A Database containing electronic medical records of the patient is available in the Patient record. Another two Databases contain information about the employees of the hospital and various infrastructure facilities available in the hospital. Reliability is the fundamental requirement of HIS. That is, whenever the system fails, an alternative mechanism needs to be devised to protect the privacy and integrity of the information present in HIS. Thus, in order to ensure reliability, the workflow of the system needs to be monitored [3]. The study presented in this paper emphasizes workflow management of healthcare services with special reference to Nephrology unit. Modeling is the process of producing a simple model that represents the construction and working of the system of interest. The purpose of a model is to enable the analyst to predict the effect of changes to the system. It may be a close approximation to the real system and incorporate most of its salient features. It should be simple to provide ease of understanding.

A good model is a judicious trade-off between realism and simplicity. Validation of model is an important issue in modeling [1], [3]. Validation technique includes simulation of the model under known input conditions and comparison of the model output with system output. Several Mathematical models have been proposed in the literature [4], [5].

Petri Net (PN) is a mathematical model introduced in 1962 by Dr. Carl Adam Petri [1]. It is a powerful modeling formalism in computer science, system engineering and many other disciplines [5], [6], [7], [8], [9], [10], [11], [12]. It combines a well-defined mathematical theory with a graphical representation to analyze the dynamic behavior of system of interest. The theoretical aspect of Petri net allows precise modeling and analysis of system behavior, while the graphical representation enables visualization of the modeled system state changes. This combination is the main reason for the great success of Petri net [1].

The main purpose of a workflow management in Hospitals is to efficiently synchronize and coordinate various processes undergone by the patient. It becomes vital to use an established framework for modeling and analyzing workflow processes [3], [5]. In this paper, a workflow framework based on Petri net model is proposed to improve the reliability of health care services related to Nephrology unit.

Incidence of Chronic Kidney Disease (CKD) is increasing worldwide at an annual growth rate of 8% [13]. Recent Survey states that the prevalence of CKD is higher in developing countries than in the developed countries. The most common causes of CKD in India are chronic glomerulo nephritis and

systemic hypertension, and diabetic nephropathy. The key objective of the proposed workflow management framework is to automate and optimize the clinical procedures undergone by patient posing CKD in a hospital environment.

The rest of the paper is organized as follows: In section 2, the state-of-the-art in PN modeling workflows in Hospital Management System is discussed. In section 3, the proposed Petri net based reliable workflow framework is described. The simulation and the validation of the proposed framework are discussed in section 4. Finally, the conclusions and further extensions of the proposed work are presented in section 5.

II. Review of Literature

Several works reported in the literature [14], [15], [16], [17], [18], [19], [20], [21] highlighting the usage of Petri net model for Hospital Management System are available. A few works related to the proposed methodology are presented in this section. Houshang Darabi and William L. Galanter [14] have suggested a method to create comprehensive formal models using Petri net to monitor the workflow of various healthcare delivery facilities available in major hospitals. The Presented model has integrated all relevant aspects of hospital operations including the status and availability of various classes of hospital personnel, the history and status of all patients currently in the hospital, and the availability of a broad range of healthcare resources available in the hospital. P.E. Miyagi et al [12] have devised a systematic methodology for modeling and simulation of control strategies in Intelligent Buildings systems through a Petri net approach. The effectiveness of time continuous Petri net model has allowed the definition of suitable optimization problems in order to optimize the devised methodology, by applying to an elevator system and HVAC system.

M.Dotoli et al [15] have presented Timed Petri net based management framework to monitor the workflow of drug distribution system and mobility of patients in the Pulmonology department of the general hospital of Bari, Italy. M.Dotoli et al [16] have described a concise timed continuous Petri net framework to model the flow of patients in a hospital, starting from their arrival to the emergency medical service, to the assignment of a bed in the appropriate department until their discharge.

Dong-Sheng Zhai et al., [18] have presented a Multi-Agent based architecture for a distributed environment scanning system. A scheduling model to optimize the average waiting time of tasks and agent has been built using Hierarchical Timed Colored Petri net (HTCP-net) model.

In this paper, a Petri net based reliable workflow management frame-work is proposed for Nephrology units in a hospital environment. Initially, the various causes and treatment procedures adopted in hospital for Kidney related problems are described. The aim of the proposed work is to monitor managerial activities like patient management, hospital staff task assignment and utilization of clinical equipment in the Nephrology unit. The proposed framework is adaptive due to the dynamic characteristics of Petri net model.

III. Proposed Petri Net Based Reliable Workflow Framework

Millions of people around the world suffer from Kidney diseases, and these patients will eventually need renal replacement therapy. Whenever the kidney is damaged for more than 3 months or Glomerular Filtration Rate (GFR) is 60 mL/min/1.73 m2, it results in Chronic Kidney Disease (CKD). Kidney damage is defined as structural or functional abnormalities of the Kidney. Most of the time, the severity of CKD may lead to Chronic Renal Failure (CRF) [13]. Chronic Renal Failure occurs when GFR gets decreased to 15 mL/min/1.73 m2. When the stage of Uremia is reached, the treatment to be executed is renal replacement therapy which reduces the risk of mortality and morbidity.

The proposed Petri net based reliable workflow management framework is a generic framework which addresses all stages of kidney disease. The key objective is to optimize the waiting time of the patient in various levels of the treatment. Further, it also enables proper management of hospital resources ensuring reliability.

A. System Description Of The Proposed Work Flow Framework

Basic workflow model of the proposed Petri net based reliable framework is shown in Fig 1. Arrival of patients to the hospital occurs at random instants of time. The proposed framework serves various categories of patients like new patients, regular patients, patients undergoing only clinical procedures, and critical patients.

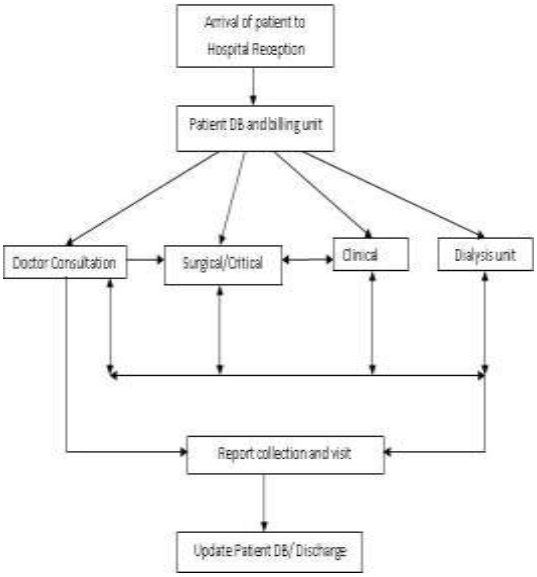

Figure 1. Basic workflow model of the proposed PN based Workflow Framework

The proposed framework consists of four sections, namely consultation, surgical ward/CCU, clinical and dialysis. Initially the arrival of patient is registered in the database available in the reception of the hospital. From the information created in the database, the category of the patient as mentioned above is determined. If the patient is new, then a new record is created with reports received from the doctor after consultation. On the other hand, for a regular patient, based on the history of

disease, retrieved from the database system, appropriate diagnosis is carried out.

Patients with Chronic Kidney Disease (CKD) visiting the hospital for clinical tests are directed to the respective clinical procedure with the help of a care taker after confirming billing.

Finally, if the patient is in the critical stage, he/she either directed to surgical unit or Critical Care Unit (CCU) for necessary treatment. As far as the clinical procedure is concerned, the patient is made to wait in the queue, if the particular section is not readily available.

Normal clinical test conducted to examine GFR of the kidney are Blood Pressure (BP) test, Blood Creatinine test. Urine culture is studied based on the result of the urinalysis test. Scanning of kidney is performed to determine the percentage kidney damage. Based on the reports generated from the above mentioned medical examinations, the severity of the disease is diagnosed. The patient can be either advised to undergo dialysis or medication or kidney transplantation.

To undergo any type of surgery, the patient has to consult the surgeon and make payment of necessary fees. When a patient completes the clinical treatment procedures, he/she has to purchase medicines prescribed from the Pharmacy. In any case, after completion of each treatment process, a report is drawn and is collected at the Database section with the confirmation from the billing section. The Database section updates the record of the patient and informs them of future appointments. After completing all the due procedures for the visit and updating the Database, the patient leaves the hospital.

B. System Modeling using Petri net

Petri net (PN) is a particular kind of bipartite directed graphs populated by three types of objects, namely places, transitions, and directed arcs. In its simplest form, a Petri net can be represented by a transition together with an input place and an output place. This elementary net may be used to represent various aspects of the modeled systems.

The proposed framework is modeled using Petri nets. Each activity involved in the framework is represented by a place with an input transition showing the beginning of the activity and an output transition indicating the end of the activity. In order to study the dynamic behavior of the modeled system in terms of its states and state changes, each place potentially holds either none or a positive number of tokens. Tokens are a primitive concept for Petri nets in addition to places and transitions. The presence or absence of token (patient) in a place (Dialysis unit) indicates whether a condition associated with the place is true (patient is undergoing Dialysis procedure) or false (patient is not available in the Dialysis unit).

C. Workflow Definitions

Definition 1: A Petri net N = (P, T, F, W) is given by a finite set of places P = {p_1 p_2 p_n}, a finite set of transitions T = {t_1 t_2 t_k} disjoint from P, a flow relation F $\subseteq$ (P * T) $\cup$ (T * P) and weight function W: F$\rightarrow$N, where N denotes the set of non-negative integers.

Definition 2: Let X = P $\cup$ T. For an element x $\in$ X the set •x = {v / (v, x) $\in$F} is the set of input elements of x and x• = {u / (x, u) $\in$ F} is the set of output elements of x.

Definition 3: A marking in a Petri net is an assignment of tokens to the places of a Petri net. Tokens reside in the places of a Petri net. The number and position of tokens may change during the execution of a Petri net. The tokens are used to define the execution of a Petri net.

Definition 4: A marking of a Petri net is a function m: P$\rightarrow$N. The global state of a Petri net is represented by a marking m $\in$ N^n. m(p), denotes the number of tokens of the place p in the marking m $\in$ N^n. m_0 is used to denote the initial marking of a Petri net.

In a graphical representation of a Petri net, circles are used to denote places; rectangular boxes/ lines are used to denote transitions; directed arcs are used to connect places to transitions and to connect transitions to places; small black dots are used as tokens to represent a marking.

Definition 5: The dynamic behavior of Petri net is represented by ring of transitions. A transition t $\in$ T of a Petri net N has a concession or can fire or is enabled at the marking m, if m(p) $\geq$ W(p, t) for all p $\in$ •t. This is denoted by m [t >. If t is enabled at the marking m, it fires and leads to a new marking m' $\in$ N^n, where this ring relation is denoted by m[t > m'

$$m'(p) = \begin{cases} m(p) - W(p,t) & \text{if } p \in {\bullet t} \setminus t^{\bullet} \\ m(p) + W(p,t) & \text{if } p \in t^{\bullet} \setminus {\bullet t} \\ m(p) - W(p,t) + W(t,p) & \text{if } p \in {\bullet t} \cap t^{\bullet} \\ m(p) & \text{otherwise} \end{cases}$$

Definition 6: Let β denote a finite sequence of transitions. The ring relation is recursively extended to finite sequence of transitions by m[βt > m' $\Rightarrow$ m[β > m" and m" [t > m' for all m $\in$ N^n and t $\in$ T.

Definition 7: The marking m' is said to be reachable from the marking m0 if $\exists$ β such that m_0[β > m'. The set of all markings reachable from the initial marking m_0 of a Petri net N is denoted by R(N, m_0) or R(N).

PN used for modeling real systems are sometimes referred to as Condition/Events system. Places identify the conditions of the parts of the system (working, idle, queuing, and failed), and transitions describe the passage from one condition to another (end of a task, failure, repair). An event occurs (a transition results) when all the conditions are satisfied (input places are marked) and concession given to the event. Occurrence of the event modifies in whole or in part the status of the conditions (marking). The number of tokens in a place can be used to identify the number of resources lying in the condition denoted by that place.

TABLE I. DESCRIPTION OF PLACES IN THE PROPOSED FRAMEWORK

PLACE	NAME	DESCRIPTION
p_1	Reception	Arrival of patient in the hospital
p_2	Database section	Creation and maintenance of patient records
p_3	Cash counter	Collection of fees for the

		treatment
p_4	Waiting hall	Queuing of Patients for treatment
p_5	Laboratory	Execution of clinical tests like BP, GFR and Urine analysis
p_6	Doctor's office	Physical examination of patients and treatment recommended
p_7	Surgeon's consulting room	Consultation with Surgeon for operation
p_8	Operation theatre	Perform operation like Fistula vein for Dialysis or kidney transplant for critical patients
p_9	Nurse station	Nurses present in the Dialysis unit to carry out dialysis for patients
p_{10}	Dialysis unit	Patient undergoing dialysis
p_{11}	Pharmacy	Availability of medicines prescribed by the Doctor
p_{12}	Care taker	Nurse or family member accompanying the Patient

These places are the main components involved in the work flow of the Nephrology unit in the hospital. Table 2 shows the description of the transitions in the proposed Petri net based reliable workflow framework. These transitions are the main clinical procedures involved in the kidney disease treatment observed in a typical Nephrology unit of a hospital.

TABLE II. DESCRIPTION OF TRANSITIONS IN THE PROPOSED FRAMEWORK

TRANSI -TION	NAME	DESCRIPTION
t_1	Registration / Authentication	New patients-registration Old patients-authentication using RFID
t_2	Billing	Registration, consultation, dialysis or operation fees
t_3	Queued up for treatment	Patients waiting in queue
t_4	Visit laboratory to conduct clinical test	Patient visiting laboratory to take test or collect report
t_5	Queued up for next procedure	Patient waiting for report collection or for doctor consultation
t_6	Consultation	Examination of report by doctor and recommendation of treatment
t_7	Execution of treatment	Execution of treatment as recommended by doctor
t_8	Consultation with surgeon	Obtain opinion from surgeon to check the patient condition
t_9	Requesting patient to make payment for operation charges	Check whether the patient has paid the charges to undergo surgery
t_{10}	Report collection from Doctor	Patients with insufficient funds postponing surgery are prescribed with relevant medications and diet
t_{11}	Surgery	Patient confirmed of payment undergoes surgery and taken toward
t_{12}	Discharge from hospital	Well recovered patient collects reports and medicines as prescribed
t_{13}	Testing of Blood Pressure	Patient with normal Blood Pressure undergo dialysis
t_{14}	Abnormal Blood Pressure	Medications given to patient to attain normal Blood Pressure
t_{15}	Dialysis	Patient undergoes dialysis (hemodialysis or peritoneal)
t_{16}	Report collection	Collect the treatment reports and medicines as prescribed
t_{17}	Update database	After collecting the reports and medicines, patient must update his/her profile information in the DB

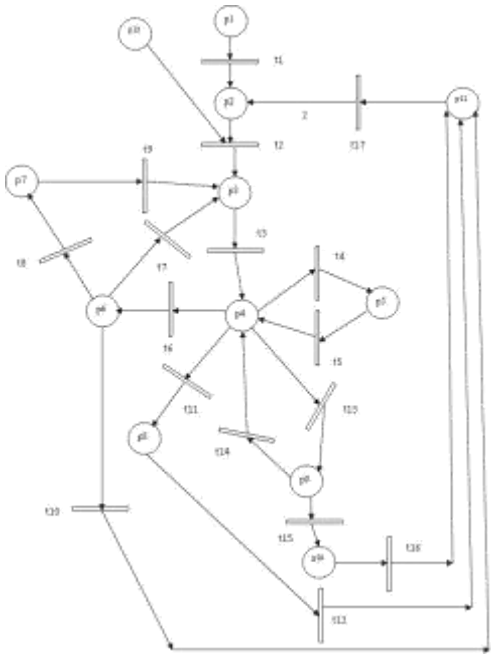

Figure 2. Proposed Petri net for Nephrology unit

IV. RESULTS AND DISCUSSIONS

The proposed PN model for Nephrology unit in a hospital environment is simulated and validated using HPSim version1.1 software tool. HPSim tool is user-friendly and easily understandable as it possesses a Graphical editor. Simulation and analysis can be carried out at a faster rate. Further, it is compatible with any version of Microsoft Windows Operating Systems (95, 98, NT, 2000, XP, Vista or higher).

The Petri net model for the proposed framework is designed by drag-and-drop of places, transitions and directed arcs from the editor bar located on the right corner of the editor window. The properties of all the three elements are defined in the project explorer window located on the left corner of the editor window. The properties defined for places are: name, size, initial tokens, current tokens, capacity and tokens count. Similarly attributes defined for transition are: initial delay, range delay, current delay and tokens red. The constructed PN model consisting of 12 places and 17 transitions are shown in Fig 3. Initial state of the proposed PN model contains two tokens. The token in p_1 represents the arrival of the patient suffering from Nephrology problem. The token in p_{12} represents the care taker assisting the patient undergoing clinical treatment.

 ISSN: 2321-8169
858 – 864

The Petri net model for the proposed framework is designed by drag-and-drop of places, transitions and directed arcs from the editor bar located on the right corner of the editor window. The properties of all the three elements are defined in the project explorer window located on the left corner of the editor window. The properties defined for places are: name, size, initial tokens, current tokens, capacity and tokens count.

Similarly attributes defined for transition are: initial delay, range delay, current delay and tokens red. The constructed PN model consisting of 12 places and 17 transitions are shown in Fig 3. Initial state of the proposed PN model contains two tokens. The token in p_1 represents the arrival of the patient suffering from Nephrology problem. The token in p_{12} represents the care taker assisting the patient undergoing clinical treatment.

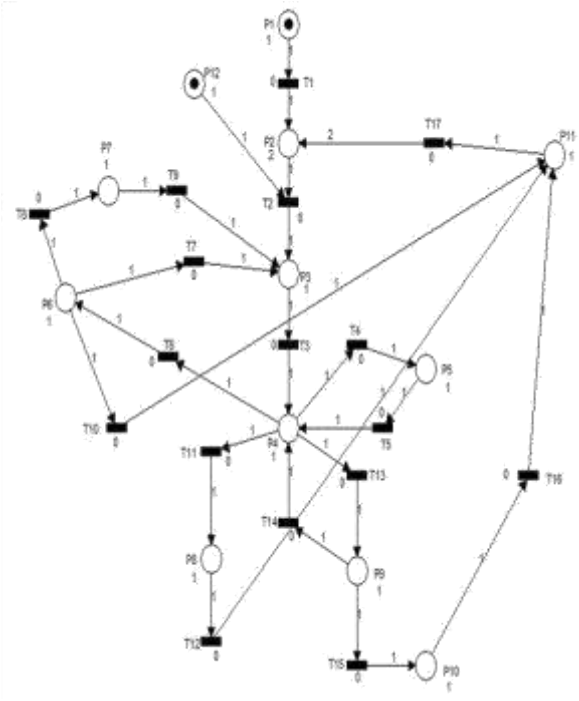

Figure 3. Initial state of PN model

Transition is enabled using the step button present in the tool. The intermediate stages of the model can be viewed using status window as illustrated in Fig 4. Movement of different class of patients and corresponding treatment undergone are traced and analyzed/studied by our patient work flow model. Final stage of the model is attained when both the tokens (patient and care taker) reach the place p_2 (Database section) indicating the completion of the treatment procedure as shown in Fig 5.

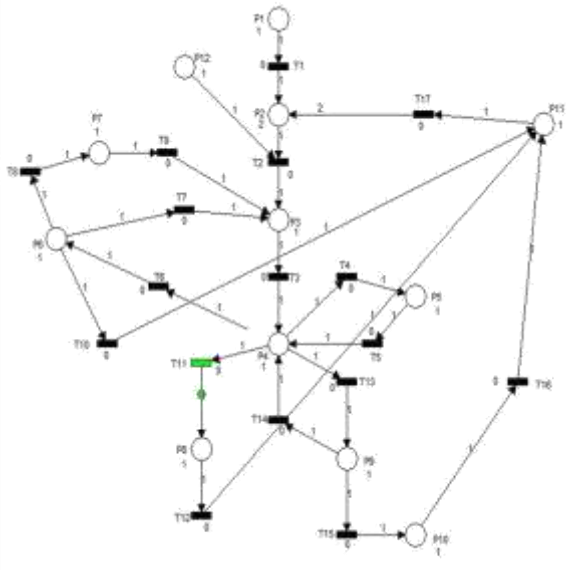

Figure 4. Intermediate stage of PN model

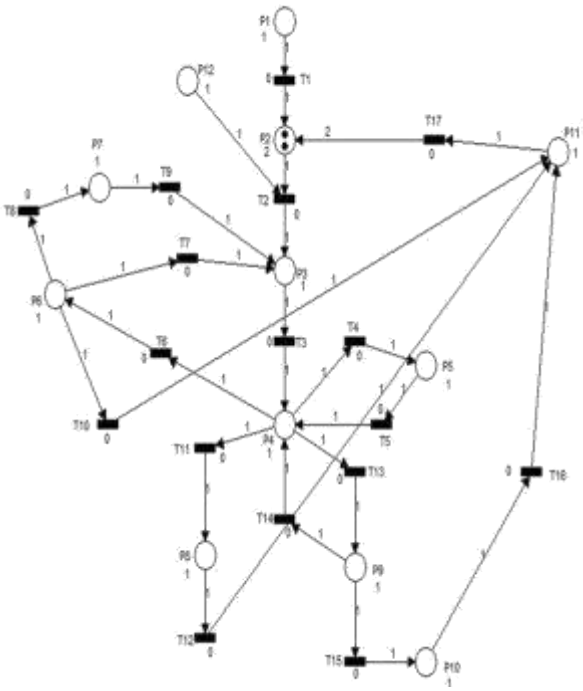

Figure 5. Final state of PN model

The proposed framework is validated using Reachability graph as shown in Fig 6. It is seen that the initial marking contains two tokens, one in p_1 and the other in p_{12}. In the final marking both tokens reach the place p_2 validating the correctness of the model.

 ISSN: 2321-8169
858 – 864

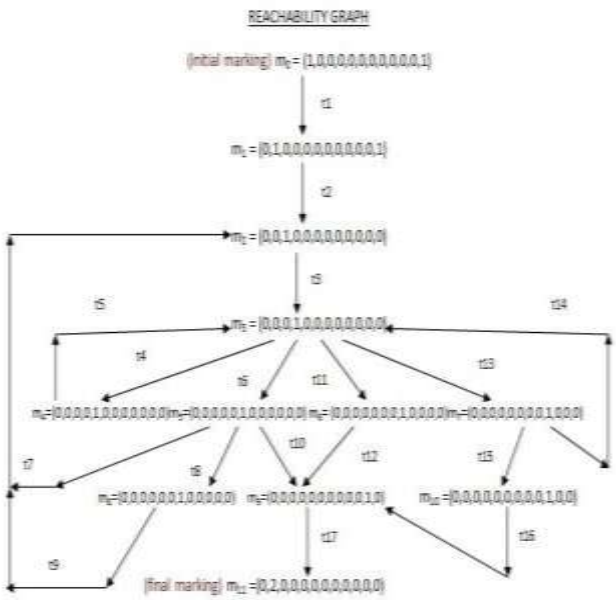

Figure 6. Validation of PN model through Reachability graph

V. CASE STUDY

The proposed work flow framework supports four different categories of patients, namely new patient, regular patient, patient undergoing only clinical procedure, and critical patient. The work flow of the model is analyzed for all these cases. The set of sequence of transitions obtained from the Reachability graph R(N) for different cases is presented in Table 3.

TABLE III. SEQUENCE OF TRANSITIONS OBTAINED FROM REACHABILITY GRAPH

S.NO	CATEGORY OF PATIENT	SEQUENCE OF TRANSITION
1	New patient	$t_1\ t_2\ t_3\ t_6\ t_7\ t_3\ t_4\ t_5\ t_6\ t_8\ t_9\ t_3\ t_{11}\ t_{12}\ t_{17}$
2	Regular patient	$t_1\ t_2\ t_3\ t_{13}\ t_{15}\ t_{16}\ t_{17}$
3	Patient undergoing only clinical procedure	$t_1\ t_2\ t_3\ t_4\ t_5\ t_6\ t_{10}\ t_{17}$
4	Critical patient	$t_1\ t_2\ t_3\ t_6\ t_8\ t_9\ t_{11}\ t_{12}\ t_{17}$

VI. CONCLUSION AND FUTURE WORK

In this paper, a PN based reliable work flow framework for Nephrology unit in hospital environment is designed. The objective of the framework is to provide a well-organized health care unit to reduce the waiting time of the resource/ patient. The framework is modeled using simple Petri net model. The proposed model is simulated in HPSim version 1.1 tools and analyzed through Reachability graph for safe termination. It is observed that the constructed Petri net is live and no deadlocks are encountered. Conflict transitions are only transitions that model regular continuation and final termination, such as (t_4, t_6, t_{11}, t_{13}), (t_7, t_8, t_{10}). These conflicts describe mutually exclusive actions. From the simulation results, it is inferred that the constructed Petri net is error-free. Hence, our proposed Petri net model is analyzed and verified using the Reachability graph which is found to be finite and reachable. Further, the proposed workflow framework can be extended for other units like Cardiology department, Orthopaedics, etc to support a multi-specialty environment.

ACKNOWLEDGMENT

We whole heartedly thank **Dr. K. Thirusangu**, Department of Mathematics, SIVET College, Chennai for the guidance provided in performing the work flow analysis using the developed Petri Net model.

REFERENCES

[1] Wolfgang Reisig, Petrinets An Introduction Monographs on Theoretical Computer Science, Springer-Verlag Berlin Heidelberg, Tokyo, Volume 4 (1950), 1-160.

[2] David Dagan Feng, Biomedical Information Technology, Academic Press, I[st] edition (2007), 1-552.

[3] Aalst, W. Van der, Hee, K. van, Work flow Management: Models, Methods and Systems, MIT Press, Massachusetts I[st] edtion (2002), 1-368.

[4] B. Baumgarten, Petri nets basics and applications, Berlin, Spectrum Akademischer Verlag, 2[nd] edition (2007).

[5] Haifeng Xie, Thierry J. Chaussalet, and Peter H. Millard. Baumgarten, A Model-Based Approach to the Analysis of Patterns of Length of Stay in Institutional Long-Term Care, IEEE Transactions on Information Technology in Biomedicine, Volume=10, Number=3 (2006), 512-518.

[6] Wang, J, Charging information collection modeling and analysis of GPRS networks, IEEE Transactions on Systems, Man and Cybernetics. Part (C), Volume = 36, Number = 6 (2006), 1-17.

[7] Tsai, J., S. Yang, and Y. Chang, Timing constraint Petri nets and their application to schedulability analysis of real-time system specifications, IEEE Transactions on Software Engineering Volume = 21,Number = 1(1995), 32-49.

[8] Tadao Murata, Petri nets: Properties, analysis and applications, Proceedings of the IEEE Volume =77, Number =4(1989), 541-580.

[9] P.E.Miyagi, E.Villani, G.D.B.Gustin, N.Maruyama, D.J.Santos Filho, Petri net approach for modeling system integration in intelligent buildings, Journal of Brazilian society of Mechanical Engineering Volume = 24, Number = 4 (2002).

[10] C. O. Alebiosu, O. E. Ayodele, The Global Burden of Chronic Kidney Disease and the way forward, PubMed, Volume = 15, 418-523.

[11] David, R and Alla, H , Petri nets for modeling of dynamic systems A survey, Journal on Automatica Volume = 30, Number = 2 (1994), 175-2002.

[12] Housang Darabi and William L.Galanter, Modeling and Integration of Hospital Information Systems with Petri Nets, IEEE International conference on Service Operations, Logistics and Informatics, Chicago (2009), 190-195.

[13] M.Dotoli, M.P.Fanti, G.Iacobellis, L.Martino, A.M.Moretti and W.Ukovich , Modeling and Management of a Hospital Department via Petri nets, IEEE workshop on Health Care Management (2010), 1-6.

[14] M.Dotoli, M.P.Fanti, A.M.Mangini, W.Ukovich, Modeling and Management of a Hospital Department via Petri nets, International Workshop on Modeling and Applied Simulation (2008).

ISSN: 2321-8169
858 – 864

[15] M.Dotoli, M.P.Fanti, G.Iacobellis, L.Martino, A.M.Moretti and W.Ukovich, Modeling and Design of Hospital Departments by Timed Continuous Petri nets, IEEE workshop on Health Care Management (2010), 1-6.

[16] Vijay Gehlot and Elliot B. Sloane, Application of the Petri Net to Simulate and Validate Complex, Multi-Vendor, Heterogeneous Networks of Wireless Medical Device Systems, Proceedings of the 10th Americas Conference on Information Systems (2004), 4631-4636.

[17] Dong-Sheng Zhai, Li-Jing Chai, Li Li, Multi-Agent Scheduling System Modeling and Simulation Based on Hierarchical Timed Colored Petri Net, International Conference on Web Information Systems and Mining (2009), 423-426.

[18] H.H. Xiong, M.C. Zhou, C.N.Manikopoulos, Modeling and Performance Analysis of Medical Services Systems Using Petri Nets, Proceedings of IEEE International Conference on Systems, Man and Cybernetics (1994), 2339-2342.

[19] S. S. Choi, M.K. Choi, W.J. Song, S.H. Son, Ubiquitous RFID Healthcare Systems Analysis on PhysioNet Grid Portal Services Using Petri Nets,Proceedings of IEEE ICICS (2005),1254-1258.

[20] Mourtou Efstratia, Abdel-Badeeh M. Salem, and Pavlidis George, Modelling and Analyzing a Hospital Procedure using a Petri-Net Approach, World Academy of Science, Engineering and Technology Volume =32, (20097), 98-102.

[21] Mandrioli, D.A. Morzenti, M. Pezze, P. Pietro S and S. Silva, A Petri net and logic approach to the specification and verification of real time systems in formal methods for Real Time Computing, John Wiley and Sons Ltd (1996)