Performance Analysis of Routing Algorithms in 2D Mesh Based NoC Under Varying Load Using Support Vector Machine

Nidhi Syal[1], Vivek Kumar Sehgal[2]
[1,2]*Department of Comp. Sci. &Eng.,*
[1]*Uttarakhand Technical University, Dehradun*
[2]*Jaypee University of Information Technology,*
Waknaghat, Solan, Himachal Pradesh, INDIA-173234.
vivekseh@ieee.org

***Abstract*—The paper presents the performance analysis of routing techniques on 3x3 mesh NOC topology. The effect of load variation in delay and total network energy for different types of routing is observed. The simulation is performed on the NOXIM network on chip simulator under random traffic conditions. The research involves developing of the classification model based on support vector machine for the performance analysis of both deterministic and adaptive routing schemes. The quality parameters provided as input to the model against the performance of routing algorithms based on Network-on-Chip platform are minimum delay, minimum energy and maximum throughput.**

***Index Terms*—Classification Model; Energy; Mesh; NOC; NOXIM, Routing; Throughput.**

I. INTRODUCTION

Network on Chip (NoC) is an extension for common bus architecture for modern System on Chip (SoC) integrated with a large number of IP blocks [1]. The traditional network protocols are embedded in VLSI to accommodate large number of processing elements in defined network topology. The integration of various IP cores in regular geometry increase the scalability of SoC. In as basic network on chip model the cores designed are connected to each other and are able to communicate over a network of routers and use packet-switched method for intercommunication. The rules of conduct used in a network on chip architecture consist of general and simplified versions of basic communication protocols which are similar used in data networks. This makes it possible to use accepted and further mature concept of communication networks with some of them to mention are routing algorithms, switching techniques, flow and congestion control in Network-on- chip architecture. The technology has improved significantly reuse of resources and provides apart from providing highly flexible and scalable communication platform for the design of system on chip. For data communications between different segments present on chip, the data are converted in the form of packets and transmitted through the network. The network has a wired connection and routers for forwarding the packets from the source to the destination. Processors, memories and other IP-blocks which are better known as Intellectual property are directly connected to the routers. Which are used for further processing of data. A routing algorithm plays an important role in deciding the way the packets are to be routed and thus responsible for network's overall operational performance. Different routing algorithms are used depending upon different applications over the system. There is a need for the investigation of several routing algorithms for further improvement in the design by means of incorporating various new features against purposes [2]-[5]. The next Section explains routing algorithms, namely XY, WF, OE, NL, NF, FA and DyAD routing algorithm in greater details.

The rest of the paper is systemized as: The routing algorithms are discussed in Section II. In Section III, architecture of 2 dimensional 3×3 mesh topology NoC, is discussed. The experimental setup and performance analysis is discussed in Section IV and V. Finally, the paper is concluded in Section VI.

II. ROUTING ALGORITHMS

The routing algorithm, states that the path acquainted by a packet between the source and the destination. It is the main job involved in the network layer design of NoC. Based on where these routing decisions are made the routing is classified as source and distributed routing [6]. Routing algorithm can also be sequentially based on the adaptive. These include deterministic and adaptive routing algorithms. The path used by the source is figure-out in earlier. The XY routing is an example of deterministic routing. In adaptive routing, there are many paths possible from origin to destiny [7]. There is another routing algorithm well known as partially adaptive routing algorithms which apply restrictions on some of the paths for communication leading to deadlock. Odd-even routing is the example of one such routing algorithm. These sets of computer instruction are simple and easy to put into the use when co-related to adaptive routing. The routing based on shortest route algorithm for conversation is called minimal routing. The routing algorithm using the longest way for connection instead of smallest way is known as non-minimal routing. The non-minimal routing has been proven that, to have some advantage over minimal routing some of them to include are the possibility of network load balancing and fault tolerance [14]. In static routing the path is permanent and cannot be changed once a packet leaves the origin and moves towards destiny. But in dynamic routing the path can be changed anytime during the transit considering network conditions. Routing algorithms defined based on their implementation include lookup table and Finite

State Machine (FSM). The following table provides the description of different routing algorithms.

Table 1
Types of Routing Techniques Used Against Performance Analysis

Sr. No	Routing	Type	Features
1	XY	Distributed Deterministic	1. Simple Implementation 2. Avoid deadlock and live lock situations
2	West First (WE)	Partially Adaptive	1. Simple Implementation 2. Direction based routing e.g. Packets starts routing from west to South, South to East and East to North
3	Odd Even (OE)	Distributed Adaptive	Completes Implementation
4	North Last (NL)	Partially Adaptive	Direction based routing e.g. Packets starts routing from west to South, South to East and East to North
5	Dyad	Deterministic and Adaptive	1. Simple Implementation 2. Avoid Congestions in network and high throughput
6	Negative First (NF)	Partially Adaptive	Packets move in two paths i.e Negative (West and South) and Positive (East and North)
7	Fully Adaptive (FA)	Escape Adaptive	1. Deed lock free Routing 2. High adoptively for packet routing

III. Architecture of 2-Dimension 3x3 Mesh Topology NoC

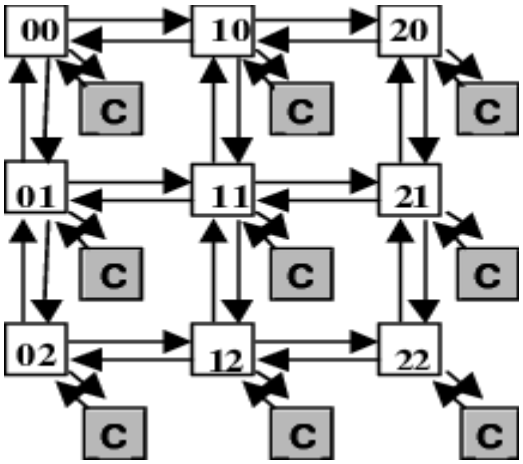

Figure 1: 3x3 mesh NoC model

The routing Algorithms are simulated for a 2-Dimension 3x3 mesh topology NoC. Where each circle represents a tile in the network. Each tile consists of an IP core is connected to a router by a bidirectional core channel (BC). The neighbor tiles are interconnected by means of a bidirectional link as (NC, EC, SC and WC). Each tile is identified by means of a unique integer ID. These can also be identified by means of a pair x-coordinate and y-coordinate. Our 2-Dimesion 3x3 mesh topology NoC is based on a switching mechanism. The packets are distributed into small segments called flits. Flits are of three types, which are known as head flit, data flit and tail flit. All the three routing algorithms, XY routing algorithm, OE routing algorithm and DyAD routing algorithms are classified on the basis of these characteristics [8]-[11].

IV. Experimental Setup

The simulation is performed on NOXIM - the NoC Simulator. The simulator is developed by the University of Catania. NOXIM is having modular design and a extendable system based on system C [12]. Simulations for all the routing algorithms were performed under same configurations under varying load. The system tiles are linked to the random traffic generator system. The packet size is of 2 bytes with random destination mode and having a buffer size of 4 bytes. The percentage load to be used is varied starting with 0.01 to 0.10 in the steps of 0.01. Simulation runs for 10000 clock cycles and the clock frequency is 2 GHz and following results related to the performance were obtained.

V. Performance Analyses

The performance analysis of the compression techniques was performed using the parameters as Total Packets Received (TPR), Global Average Throughput (GAT), Average Throughput (AT), Average Delay (AD), Global Average Throughput flits / cycles (GATF) and Total Energy (TE). The metrics are obtained from the equations as mentioned in Table 2.

A. Total Packets Received

The average of packets received for random traffic and varying load was observed to be maximum in case of XY routing (3291.1) pkts. The accepted minimum total packets received were observed for the NL routing (3056.1) pkts. There was a drop in total packets received observed for NF and FA routing algorithms when the varying load was >0.05.

Table 2
Comparison of Routing Techniques

Sr. No	Routing Techniques	Quality Parameters					
		TPR	GAT	AT	AD	GATF	TE
1	XY	3291.1	0.2253	0.26586	0.209	0.225356	3.30E-05
2	WF	3212.4	0.2154	0.25444	0.20994	0.215476	3.27E-05
3	OE	3100.1	0.2112	0.24902	0.21978	0.211294	3.38E-05
4	NL	3056.1	0.2061	0.24234	0.24468	0.206112	3.21E-05
5	DY	3119.3	0.2129	0.25068	0.23878	0.212987	3.45E-05
6	NF	805.4	0.0966	0.09062	0.02146	0.096673	1.80E-05
7	FA	643.6	0.1362	0.07075	0.03452	0.136286	6.45E-06

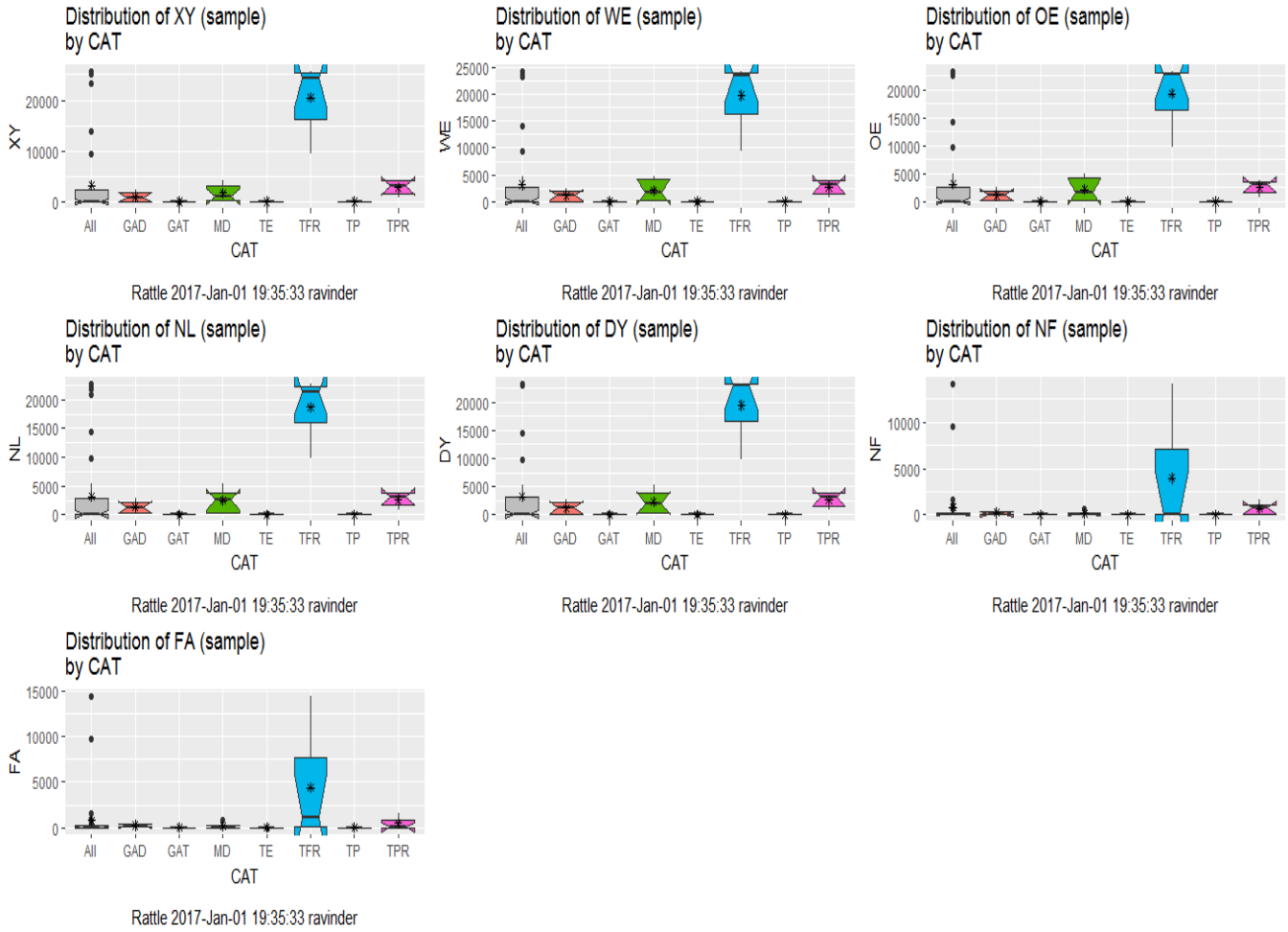

Figure 2: The comparison of routing techniques DY, FA, NF, NL, OE, WE and XY against quality parameters as mentioned in Table 2.

B. Global Average Throughput (Flits/Cycle)

The global average throughputs were also measured in terms of Number of flits/cycles. The global throughput of XY routing has maximum value i.e 0.22535 followed by West First = 0.21547, Dyadt = 0.21298, Odd Even = 0.2112, North Last = 0.20611. It was found to be Minimum against Negative First = 0.09667 & Fully Adaptive = 0.13628.

The acceptable Minimum global average throughput was fixed as North Last = 0.20611. Since Negative First and Fully Adaptive were observed to fail to perform above loads > 0.05.

C. Throughput

The throughput was also calculated in terms of flits/cycle/Ip, which was Maximum for XY having value = 0.26586. The Minimum values were observed against West First = 0.2544, Dyadt = 0.2506, Odd Even = 0.2490, North Last = 0.2423. Although, the lowest throughput values were observed for Negative First = 0.0906 and Fully Adaptive = 0.0707 so Negative First and Fully Adaptive fail to perform under loads >0.05.

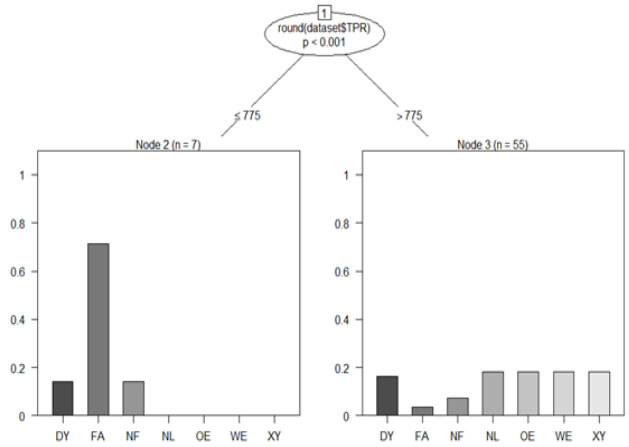

Figure 3: The grouping of compression techniques DY, FA, NF, NL, OE, WE and XY against total packet received TPR

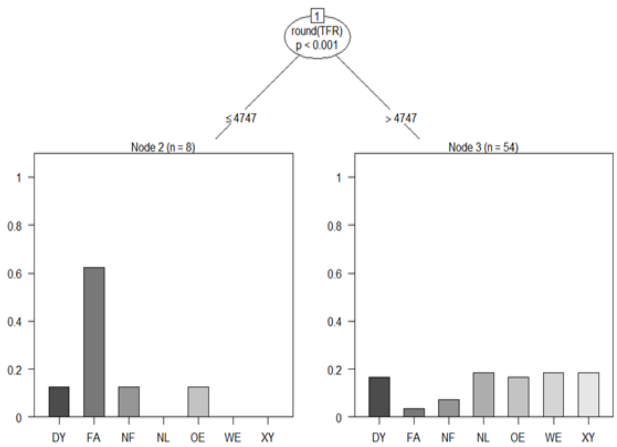

Figure 4: The grouping of compression techniques DY, FA, NF, NL, OE, WE and XY against Total Flits Received TFR

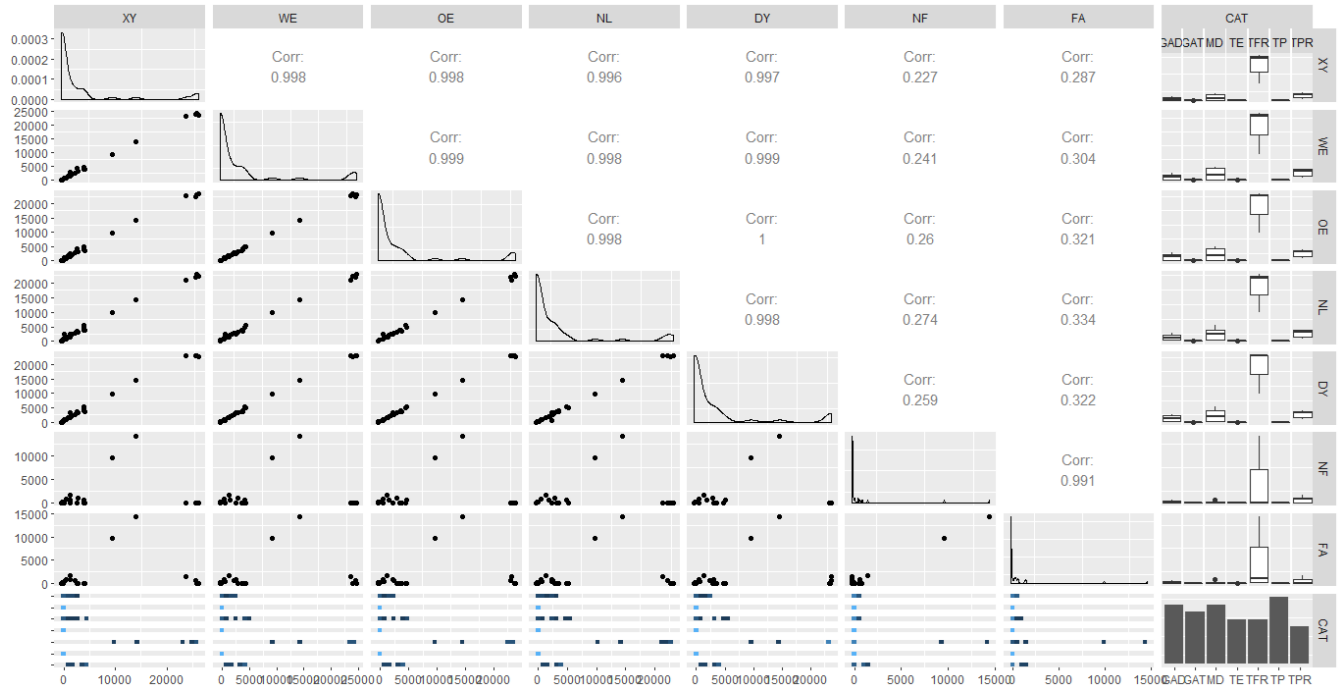

Figure 5: Linear relationship between XY, WE, OE, NL, DY, NF, and FA Routing Techniques as mentioned in Table 1

D. Average Delay

The Minimum delay was observed for XY = 0.209 followed by West First, Odd Even, Dyadt and North Last having values 0.20994, 0.21978, 0.23878, 0.24468 resp. Excluding Negative First and Fully Adaptive which have Minimum delays unable to perform under loads > 0.05.

E. Global Average Throughput (Flits/Cycles)

The global average throughput for random traffic and varying load was observed to be maximum in case of XY routing (0.225356) flits/cycles. The accepted minimum global average delay of packets received were observed for the NL routing (0.206112) flits/cycles. There was unacceptable drop in global average throughput in network observed for NF and FA routing algorithms when the varying load was >0.05.ww.

F. Total Energy

The average delay for random traffic and varying load was observed to be maximum in case of DY routing (3.45E-05) J. The accepted minimum global average delay of packets received was observed for the NL routing (3.21E-05) J. There was an unacceptable drop in average throughput in network observed for NF and FA routing algorithms when the varying load was > 0.05.The total 72 samples were analyzed and two groups were formed. The one with 55 cases were having total packets received (TPR) > 775 and second having 7 cases with total packets received (TPR) < 775.The routing techniques NL, OE, WE and XY were not present in the second group. Which indicates total packets received (TPR) was high for NL,OE,WE and XY while it was observed to be low for DY ,FA and NF. The total 72 samples were analyzed and two groups were formed. The one with 54 cases were having total flits received (TFR) > 4747 and second having 8 cases with total packets received (TFR) < 4747.The routing techniques NL,WE and XY were not present in the second group. Which indicates total flits received (TFR) was high for NL,OE,WE and XY while it was observed to be low for DY, FA, NF and OE. In the linear relationship between the routing techniques the score of XY Routing technique with WE and OE was observed to be maximum having value (0.998). While XY was having a low linear relationship score with WE , NF and OE having value (0.227). The analysis various routing techniques were performed using correlation. The values for correlations are represented by the correlation coefficients (p). The range of possible values for (p) varies from -1.0 to +1.0. The correlation coefficients (p) having values less than zero represent a negative relationship while greater than zero represent a positive relationship. Close positive relationships were established between XY, NL, WE, OE and DY. While NF and FA was observed to be in two separate groups.

VI. Conclusion and Future Scope

After comparing all the routing algorithms against the parameters including throughput, max. delay and energy the XY routing was found to perform better followed by WF, OE, NL and DY. While an unacceptable behavior was observed against NF and FA routing algorithms. In the NF and FA routing algorithms there was a drop in the total packets received leading to low throughput, low delay and low energy consumption once load reached a threshold value 0.05 in a random traffic scenario. The proposed model is good for 2-Dimension 3x3 mesh topology NoC. The same technique can be used for other topologies.

References

[1] P. Guerrier and A. Greiner, “A generic architecture for on-chip packet-switched interconnections,”Proc. Design, Automation and Test in Europe Conference and Exhibition (DATE 2000), Mar. 2000, pp. 250–256, doi:10.1109 / DATE. 2000.840047.

[2] Hemani, A. Jantsch, S. Kumar, A. Postula, J.Oberg, M. Millberg. et al, “Network on a chip: an architecture for billion transistor era,” Proc. IEEE NorChip, 2000

[3] W. Dally and B. Towles, “Route packets, not wires: on-chip interconnection networks,” Proc. Design Automation Conference, Jun.2001, pp. 684–689.

[4] M. Sqroi, M. Sheets, A. Mihal, K. Keutzer, S. Malik, J.Rabaey, et al. "Addressing the system-on-a-chip interconnect woes through communication-based design",Proc. Design Automation Conference, Jun 2001, pp.667-672.
[5] S. Kumar, A. Jantsch, J. Soininen, M. Forsell, M. Millberg, J. Oberg. et al, "A network on chip architecture and design methodology," Proc. IEEE Computer Society Annual Symposium on VLSI, Apr. 2002, pp. 105–112, doi: 0.1109/ISVLSI.2002.1016885.
[6] J. Duato, S. Yalamanchili, L. Ni, Interconnection networks: an engineering approach, Morgan Kaufmann, Revised Edition, 2002.
[7] L. M. Ni, P. K. Mckinley, "A Survey of Wormhole Routing Techniques in Direct Networks", Computer, vol. 26(2),Feb 1993, pp. 62 –76, doi: 10.1109/2.191995.
[8] M. Dehyadgari, M. Nickray, A. Afzali-kusha, Z. Navabi:Evaluation of Pseudo Adaptive XY Routing Using an Object OrientedModel for NOC. The 17th International Conference on Microelectronics, 13–15December 2005.
[9] Wang Zhang, LigangHou, Jinhui Wang, ShuqinGeng, Wuchen Wu, "Comparison Research between XY and Odd-Even Routing Algorithm of a 2-Dimension 3X3
[10] Mesh Topology Network-on-Chip", WRI Global Congress on Intelligent Systems, GSIS'09, May 2009, pp. 329-333, doi: 10.1109/GCIS.2009.110.
[11] Ge-Ming Chiu, "The odd-even turn model for adaptive routing", IEEE Transactions on parallel and distributed systems, Jul 2000, pp. 729-738 doi: 10.1109/71.877831.
[12] Jingcao Hu; Marculescu, R., "DyAD - smartrouting for networks-on-chip", 41st Proceeding of Design automation conference, San Diego, CA, USA, Jul 2004, pp. 260-263.
[13] L. Jain., "NIRGAM: A Simulator for NoC Interconnect Routing and Applications Modeling", date conference, Sep 2007, pp. 1-2.
[14] Sehgal,V.K., 2015. Markovian models based stochastic communication in networks-in-package. IEEE Transactions on Parallel and Distributed Systems, 26(10), pp.2806-2821.

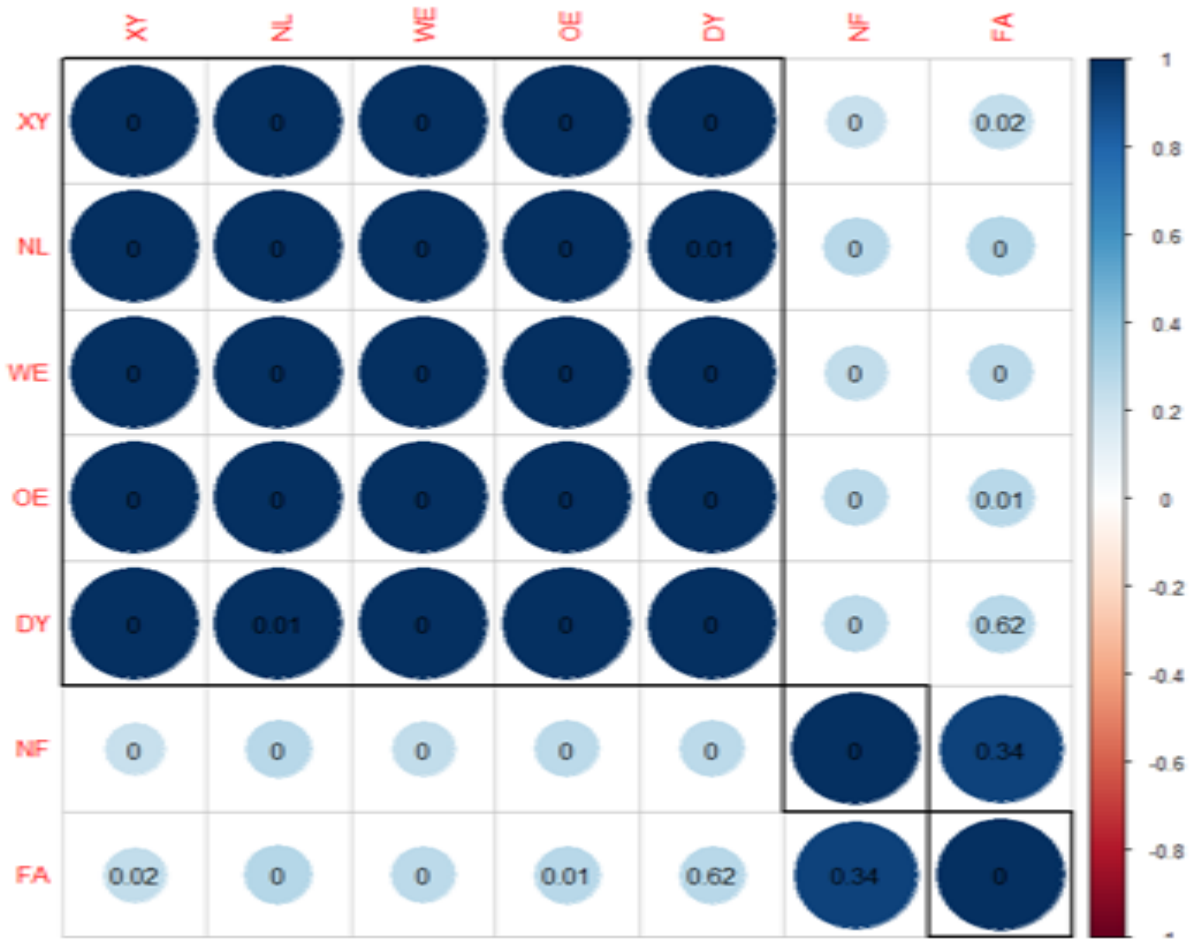

Figure 6: The Correlation map between XY, WE, OE, NL, DY, NF, and FA Routing Techniques