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Effective Network Parameters on Power Consumption in Networks on Chip

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Abstract

Objectives: To discover the impact of network parameters on power consumption in Networks on Chip (NoCs). **Methods:** Network on Chip (NoC) has been introduced as a solution for System on Chip (SoC) communication demands. Power consumption becomes a significant component in the NoCs due to the advanced VLSI technology. **Findings:** In this paper we compare the effect of network parameters such as number of nodes, size of packet length and number of virtual channels on power dissipation in NoCs. Link and total power consumption of NoC with different network parameters with and without using low power encoding algorithm is analyzed. **Application/Improvements:** A comprehensive evaluation has been accomplished to assess the effect of network parameters in the absence and presence of low power encoding approach on power dissipation in NoCs.

Keywords: Low Power Encoding, Network on Chip, Number of Node, Packet Length, Number of Virtual Channel, Power Consumption.

1. Introduction

Advanced VLSI technology motivates designers to investigate System on Chip (SoC). To overcome today's problem of SoCs, Network on Chip (NoC) has been suggested as a desirable solution[1,2]. Trend of the technology to the portable electronic systems shows the power as a most critical factor in chip design[3–5].

Many approaches are introduced to reduce the power and energy dissipation in NoCs. Some of them reduce the power consumption through optimization algorithms. These approaches are divided into two groups; analytical problems and meta-heuristic algorithms[6–15]. Another one is low power encoding techniques which are categorized as important methods to decline the power consumption in chip interconnection. Researchers in[16–20] presented various low power encoding algorithms to reduce the power dissipation. MFLP (Most Frequent Least Power) is one of the low power encoding approaches that is proposed to decrease the power consumption in NoC and in the chip as well[20].

In this paper effect of network parameters such as number of nodes, size of packet length and number of virtual channels on MFLP[20] are evaluated. MFLP[20] is a low power encoding to reduce the number of ones in the code words. Therefore, the number of switching activities is decreased due to the sending the data with transition signaling. The structure of MFLP is based on the tree to assign high probability data to the less ones symbols[20]. According to this approach most frequent symbols have least number of ones and as a result the power of NoC is decreased.

MFLP as a low power encoding algorithm has an effect on network parameters. In the following sections the effectiveness of such parameters are evaluated. The power of the NoC is dissipated in routers and links. It is worth mentioning that the power dissipation of router composed of router's power dissipation and power consumption of network interface. To evaluate router's power consumption, power compiler tool from Synopsys is registered trademarks used. Static and dynamic power consumption is considered in this evaluation.

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The link's power is calculated by $P_{link} = \propto CV_{dd}^2 f$, where $\propto$ is the link's switching activity, C is the link and coupling capacitance, the clock frequency is f and V_{dd} is the power supply of the system. 65 nm technology is used to simulate the proposed method. Based on the International Technology Roadmap for Semiconductors[21], for this technology V_{dd} is 1 Volt. According to the critical path of the system clock frequency is 500MHz. The length of the wires for mesh topology is 2 mm. The self and coupling capacitances are 0.2 pF/mm and 0.6 pF/mm, respectively. Modelsim is registered trademarks utilized to calculate the transitions of the wires. We implement the coding methods and the NoC infrastructure in VHDL.

Default of implementation for the NoC is 16 nodes with mesh topology and XY routing algorithm. The number of virtual channel per physical link is two. The traffic of packet injection is uniform and the packet length is 32.

2. Number of Nodes

In this section, the effect of the number of nodes as network parameter in NoC is determined. The networks are examined with 4, 16 and 64 nodes.

The link and the total power consumption with and without using low power encoding in NoC for different number of nodes are shown in Tables 1, 2 and 3. In the following tables, N.C stands for the No Coding. N.C columns show the power consumption without using any low power encoding approach. In the column of MFLP, the power dissipation with applying MFLP as a low power encoding algorithm is indicated. In the next column, the percentage of power improvement because of using low power encoding approach is reported.

Table 1. The link and total power consumption with 4 nodes

Node No.	2*2					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	4.38	3.04	30.59	17.73	17.64	0.48
.GIF	5.04	3.25	35.48	18.21	18.17	0.20
.WAV	4.87	2.38	51.04	18.02	17.08	5.20
.HTML	4.58	3.63	20.75	17.65	17.45	1.13
.JPG	5.35	3.09	42.13	18.56	18.03	2.85
.BMP	2.47	1.93	22.03	15.73	15.20	3.36
.PNG	3.49	2.19	37.12	16.90	16.80	0.57
.PDF	5.14	3.13	39.11	18.33	18.06	1.47
.DOCX	4.54	2.72	40.09	17.63	17.49	0.79

Table 2. The link and total power consumption with 16 nodes

Node No.	4*4					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	27.15	19.51	28.11	80.57	72.96	9.44
.GIF	31.08	20.88	32.81	84.93	75.32	11.31
.WAV	30.15	16.22	46.20	84.03	70.09	16.58
.HTML	28.25	22.78	19.38	81.76	76.87	5.98
.JPG	33.00	20.37	38.25	87.12	74.90	14.02
.BMP	15.86	12.53	20.95	70.17	65.09	7.23
.PNG	22.19	15.29	31.09	74.31	68.82	7.38
.PDF	31.83	20.35	36.04	85.89	74.93	12.76
.DOCX	28.40	18.00	36.62	81.97	72.08	12.07

Table 3. The link and total power consumption with 64 nodes

Node No.	8*8					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	124.34	96.43	22.44	337.02	332.33	1.39
.GIF	138.28	103.49	25.16	351.97	345.84	1.74
.WAV	137.10	83.39	39.17	351.35	321.26	8.56
.HTML	128.12	110.01	14.14	349.90	349.84	0.01
.JPG	146.20	101.63	30.48	360.97	344.17	4.65
.BMP	75.54	66.38	12.12	296.84	296.12	0.24
.PNG	101.84	80.32	21.12	318.74	317.56	0.36
.PDF	141.15	100.35	28.89	355.83	342.72	3.68
.DOCX	125.69	89.81	28.54	337.96	329.66	2.45

To know about the effect of number of nodes in NoC, two factors should be considered. Firstly, consecutiveness of data that is an effective criterion on MFLP. When the data is consecutive, the chance of interference among the data decrease and consequently MFLP is more effective in power reduction. Based on the above remarks, with increment of number of virtual channels in NoC the interference among the data goes up and consecutiveness of data decline. Therefore, MFLP is not effective as much as short distance in NoC and consequently, power dissipation increase.

Another criterion which is relevant to the distance between the sender and receiver is self and coupling capacitance. It is clear that with increasing the distance

the capacitance increased as well. As shown in the above tables, with increasing the size of the NoC the improvement in link's power consumption is declined. The reason of this reduction is because of the interference among the data. From total power dissipation perspective, the NoC with 16 nodes is the best one. As mentioned two factors; consecutiveness of the data and link's capacitance should be considered. Moreover, we need to know which one is more effective. In this case with increasing the size of the NoC from 4 to 16 nodes, link's capacitance increase while data is more or less consecutive. However, when we increase the number of nodes to 64, although the capacitance of the path goes up, the consecutiveness of the data collapses and it has a bad effect on the effectiveness of MFLP.

3. Size of the Packet Length

MFLP is tested with various sizes in packet length. The link and the total power consumption with and without using low power encoding in NoC for different size of packet length are shown in Tables 4–6.

Table 4. The link and total power consumption with packet length of 16

Packet Length	16					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	26.33	19.39	26.32	80.48	73.68	8.43
.GIF	28.26	19.52	30.92	82.55	74.50	9.75
.WAV	28.63	17.13	40.17	83.04	71.96	13.34
.HTML	26.80	21.17	20.98	80.96	75.86	6.29
.JPG	29.46	19.20	34.83	83.92	74.37	11.38
.BMP	20.22	15.71	22.26	74.71	69.76	6.62
.PNG	23.80	16.31	31.47	77.15	70.73	8.32
.PDF	28.63	19.21	32.89	83.04	74.50	10.28
.DOCX	27.06	17.97	33.59	81.24	72.86	10.31

Table 5. The link and total power consumption with packet length of 32

Packet Length	32					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	27.15	19.51	28.11	80.57	72.96	9.44
.GIF	31.08	20.88	32.81	84.93	75.32	11.31
.WAV	30.15	16.22	46.20	84.03	70.09	16.58
.HTML	28.25	22.78	19.38	81.76	76.87	5.98
.JPG	33.00	20.37	38.25	87.12	74.90	14.02
.BMP	15.86	12.53	20.95	70.17	65.09	7.23
.PNG	22.19	15.29	31.09	74.31	68.82	7.38
.PDF	31.83	20.35	36.04	85.89	74.93	12.76
.DOCX	28.40	18.00	36.62	81.97	72.08	12.07

Table 6. The link and total power consumption with packet length of 64

Packet Length	64					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	28.50	20.04	29.69	81.42	72.79	10.60
.GIF	34.21	21.13	38.20	87.85	74.93	14.70
.WAV	31.98	16.59	48.12	85.62	69.83	18.44
.HTML	31.23	24.43	21.76	84.37	78.05	7.49
.JPG	35.95	20.70	42.39	89.84	74.62	16.94
.BMP	15.59	11.21	28.11	69.79	62.86	9.92
.PNG	22.64	14.81	34.55	74.08	67.64	8.68
.PDF	35.35	20.36	42.37	89.33	74.31	16.81
.DOCX	29.70	17.82	39.98	82.75	71.19	13.97

Experimental results show that MFLP is more effective if the packet length in the NoC is increased. In other words, the improvement in the link and the total power dissipation is better. MFLP is implemented in the transport layer. Therefore, the data part of the flits is coded in the sender and receiver nodes and header

or footer is remained without any changes. In other words, by changing the packet size, the number of data change which is supposed to be coded is changed and consequently the effectiveness of MFLP is affected. As shown, with increasing the packet length, the impact of the proposed method is improved.

4. Number of Virtual Channels

We study the effect of numbers of virtual channels on MFLP. Performance and power consumption of NoC is affected with number of virtual channels. Tables 7, 8 and 9 compare the link and total power consumption with and without using low power encoding algorithm in NoC with various number of virtual channels.

Table 7. The link and total power consumption with 1 virtual channel

Virtual Channel	1					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	14.94	10.32	30.92	37.42	35.64	4.76
.GIF	18.19	10.90	40.07	41.05	36.74	10.50
.WAV	16.55	8.18	50.55	39.25	33.66	14.23
.HTML	15.79	12.09	23.39	38.35	37.80	1.43
.JPG	19.27	10.44	45.82	42.17	36.31	13.89
.BMP	9.25	6.66	27.90	32.30	31.49	2.51
.PNG	12.74	7.26	42.98	35.03	32.56	7.05
.PDF	18.36	10.44	43.11	41.23	36.33	11.89
.DOCX	16.54	9.20	44.38	39.26	34.84	11.25

Table 8. The link and total power consumption with 2 virtual channels

Virtual Channel	2					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	27.15	19.51	28.11	80.57	72.96	9.44
.GIF	31.08	20.88	32.81	84.93	75.32	11.31
.WAV	30.15	16.22	46.20	84.03	70.09	16.58
.HTML	28.25	22.78	19.38	81.76	76.87	5.98
.JPG	33.00	20.37	38.25	87.12	74.90	14.02
.BMP	15.86	12.53	20.95	70.17	65.09	7.23
.PNG	22.19	15.29	31.09	74.31	68.82	7.38
.PDF	31.83	20.35	36.04	85.89	74.93	12.76
.DOCX	28.40	18.00	36.62	81.97	72.08	12.07

Table 9. The link and total power consumption with 3 virtual channels

Virtual Channel	3					
Power	Link			Total		
File name	N.C	MFLP	Imp. (%)	N.C	MFLP	Imp. (%)
.TXT	28.53	19.75	30.76	116.27	112.95	2.85
.GIF	32.96	21.23	35.58	123.79	115.99	6.29
.WAV	31.63	16.44	48.02	120.53	110.24	8.53
.HTML	29.81	23.08	22.58	118.30	117.28	0.86
.JPG	35.02	20.71	40.86	126.14	115.63	8.33
.BMP	16.61	12.62	24.03	105.72	104.13	1.50
.PNG	23.30	15.45	33.68	113.56	108.75	4.22
.PDF	33.65	20.59	38.80	124.37	115.49	7.13
.DOCX	30.03	18.24	39.24	120.45	112.32	6.74

Regarding virtual channels two criteria should be considered; sequence of data and utilization of the bus. When the number of virtual channels increases, sequence of data collapses and consequently the power improvement reduce. On the other hand, with incrementing the number of virtual channels the congested links goes down and link's power dissipation increases. Thus, the impact of MFLP rises. It can be concluded that the efficacy of number of virtual channels on MFLP depends on sequence of data and utilization of the bus. Variety in power dissipation with changing the number of virtual channels depends on dominance of criteria. In other words, which of the criteria (sequence of data or utilization of the bus) is more subject to be changed.

5. Conclusion

In this paper, the effect of network parameters such as number of nodes, size of packet length and number of virtual channels on power consumption in MFLP which is a low power encoding algorithm[20] is studied. We discussed about effect of using low power encoding approach in link and total power dissipation in NoC. Based on the above remarks it can be concluded that network parameters in different characteristics, with and without using low power encoding have an effect on power consumption in NoC.

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