

Chapter 6

Conclusion

This thesis has proposed two methods to improve the performance of banyan networks: the hybrid dilated banyan network method and the bypasses method. Studying these methods, the followings are proposed. The hybrid dilated banyan network is constructed by the 2-dilated banyan switching elements and banyan switching elements to reduce hardware size from the 2-dilated banyan network and to obtain higher output rate than the original banyan network. The bypasses are inserted at switching elements of the original, the 2-dilated and hybrid dilated banyan networks to improve the output rates of these networks. Three kinds of bypass connecting methods (all-bypass-connection, one-bypass-connection and one-bypass-connection at two neighbor stages) for switching cells are also introduced to provide system designers with useful delay options.

For the performance analysis, the original banyan network, the hybrid dilated banyan network and the 2-dilated banyan network with and without bypasses are compared with each other by the following conditions: Switching efficiency (output rate), delay, hardware size and flexibility. Table 6.1 shows the results for the $2^8 \times 2^8$ networks at the input rate 1.0. More detailed estimations for delay and hardware size are shown in Appendix A.2.

From table 6.1, the 2-dilated banyan networks with bypasses have the highest output rate, but have the largest delay and hardware size with no flexibility. The 2-dilated banyan networks without bypasses have no flexibility. Their output rates are less than the one of the networks with bypasses. However, they have less delay and hardware size than the networks with bypasses.

The hybrid dilated banyan networks with bypasses offer the output rate during 0.371 to 0.574 which is lower than the 2-dilated banyan networks with bypasses, however, in the case of all-bypass-connection, their output rate is higher than 2-dilated banyan networks without bypass. The hybrid dilated banyan networks without bypass provide the output rate during 0.315 to 0.500. Delay and hardware size of the hybrid dilated banyan networks depend on

the number of 2-dilated banyan switching elements and the kinds of bypass-connection when the bypasses are used in the networks. These networks have good flexibility because network designers can request their output performance and are able to concern on their delay and hardware size.

	Switching efficiency	Delay and Hardware size	Flexibility
2-dilated banyan network with bypasses	0.643 (all-bypass) 0.607 (one-bypass)	largest	none
2-dilated banyan network without bypasses	0.572	large	none
Hybrid dilated banyan network with bypasses	0.371 to 0.574	depend on the number of 2-dilated banyan switching element and the kind of bypass-connection	good
Hybrid dilated banyan network without bypasses	0.315 to 0.500	depend on the number of 2-dilated banyan switching element, but is smaller than the one with bypass	good
Original banyan network with bypasses	0.448 (all-bypass) 0.356 (one-bypass)	depend on the kind of bypass-connection	none
Original banyan network without bypasses	0.300	smallest	none

Table 6.1: Comparisons of the $2^8 \times 2^8$ hybrid dilated, 2-dilated banyan network and original banyan networks with and without bypasses at input rate 1.0

The original banyan networks with bypasses provide the output rate of 0.448 when all-bypass-connection is used and the one of 0.356 when one-bypass-connection is used. Their delay and hardware size depend on the types of the bypass-connection, and are smaller than the ones of the hybrid dilated banyan networks and the 2-dilated banyan networks. The original

banyan network without bypasses provides the lowest output rate of 0.300 and has the smallest delay and hardware size. Because these networks can not be requested for the variety of output performance, delay and hardware size, they do not have flexibility for network designers.

	Switching efficiency	Delay	Hardware size
all-bypass-connection	highest	largest	largest
one-bypass-connection	high	twice larger than no bypass	a little bit smaller than all-bypass
one-bypass-connection at two neighbored stages	low	smaller than one-bypass-connection	smaller than one-bypass-connection
no bypass	lowest	smallest	smallest

Table 6.2: Comparisons of networks with all-bypass-connection, one-bypass-connection, one-bypass-connection at two neighbored stages and no bypass

In this thesis, all-bypass-connection, one-bypass-connection and one-bypass-connection at two neighbored stages are used in the networks with bypasses. Table 6.2 compares between these bypass-connections and no bypass-connection in terms of switching efficiency, delay and hardware size. The all-bypass-connection network provides the highest switching efficiency (output rate), however it has the largest delay and the largest hardware size. The one-bypass-connection network provides the lower switching efficiency and smaller delay (twice larger than no bypass network) than the ones of the all-bypass-connection network. However, it has almost the same hardware size with the all-bypass-connection network. The one-bypass-connection at two neighbored stages network has lower switching efficiency and smaller delay and hardware size than the ones of the former two connections. No bypass network has the lowest switching efficiency, but the smallest delay and hardware size.

When network designers design a new network, they may consider switching efficiency (input rate and output rate), flexibility, delay, hardware size and cost of the network. The

flexibility of the hybrid dilated banyan network and the bypasses method in this thesis give the solutions for the required networks by the designers, however, it is very complicated to find such solutions from the various kinds of network constructions. The future work will propose a system automatically constructing the optimal network based on the results in this thesis.