The Study on Adaptive Routing Algorithm of 2-D Torus Network with Fault Tolerance

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***Abstract*—As an application of the turn model in a two-dimensional torus network, we propose a north-south first (NSF) algorithm. Until now, evaluations focusing on fault tolerance were inadequate because we focused on proposing a routing algorithm aimed at avoiding congestion. In this paper, we propose NFS-IP, which is a new routing algorithm with improved fault tolerance, along with an evaluation of the conventional NFS algorithm.**

I. Introduction

Numerous parallel computers combining processor elements (PEs) are currently being developed, and accordingly, many interconnection networks for them exist. Among them, a 2D torus network is a general interconnection network. There are two types of interconnection networks: deterministic routing and adaptive routing networks, with adaptive routing networks being particularly robust against failure. We improved the turn model for 2D mesh networks and proposed a north-south first (NSF) routing that made it adaptable to a 2D torus network [1] [2]. Up to now, because we focused on a proposal for a routing algorithm aimed at avoiding congestion of the interconnection network, the evaluation of fault tolerance was not sufficient. In addition, we improve conventional NSF algorithms and propose an improved NSF algorithm (NSF-IP), which is a fault-tolerant routing algorithm. For these algorithms, we evaluate both congestion resistance and fault tolerance by simulation of dynamic communication performance.

II. NSF Routing

There is a turn model that does not require an additional virtual channel as an adaptive routing algorithm for mesh networks, but if it is applied to a 2D torus as it is, a deadlock occurs. Therefore, we proposed an NFS routing that combines a north first (NF) algorithm and a south first (SF) algorithm, both of which are turn model algorithms [1], as an algorithm applicable to the 2D torus. The proposed algorithm performs routing on the basis of a restricted NF algorithm with channel-L and an SF algorithm with channel-H. With this algorithm, it is possible to implement adaptive routing on the basis of the turn model without using additional virtual channels in the 2D torus. The details of the NSF routing are shown in Fig. 1. We have already considered an NSF routing improvement plan [2], and in this paper, we propose NSF-IP as an excellent fault-tolerant algorithm.

III. NSF-IP Algorithm

The NSF-IP algorithm proposed in this paper improves fault tolerance. In this algorithm, the SF algorithm executed with

```
// Link Selection Function for Proposed Algorithm
Link_Select_Prop (cx, cy, cc, dx, dy)
  cx, cy;  // current node  0 ≦ cx, cy ≦ N－1
  cc;      // current channel  ∈{L, H, W}
  dx, dy;  // destination   0 ≦ dx, dy ≦ N－1
{
  if(dx-cx≧N/2)   h_wrap = 1;
  else            h_wrap = 0;
  if(dy-cy≧N/2)   v_wrap = 1;
  else            v_wrap = 0;
  dist_x =(N+dx-cy)%N;
  dist_y = (N+dy-cy)%N;
  if(1≦dist_y ≦N/2)                         // Y+ direction
    if(h_wrap=0 & v_wrap=0)                 return adaptive_SF(cx, dx);
    else if(h_wrap=1 & v_wrap=0)         return DOR(cx, cy, dx, cy);
    else        return DOR(cx, cy, dx, dy);
    else if(cy≠dy)                          // Y- direction
      if(cc=0)                           return adaptive_NF(cx, dx);
      else                               return DOR(cx, cy, dx, dy);
  else if(cx≠dx)                            return x_route(cx, dx);
  else                                   return OUT;
}

adaptive_SF(cx, dx){                  //adaptive routing of SF algorithm
  if(cx=dx)                                 return Y+;
  else if(buffer_is_full(Y+, H)=TRUE)    return x_route(cx, dx);
  else                                   return Y+;
}

adaptive_NF(cx, dx){                  //adaptive routing of NF algorithm
  dist_x = (N+dx-cx)%N;
  if(cx=dx)                                 return Y-;
  else if(N/2＜dist_x)                   return x_route(cx, dx);// X- direction
  else if(buffer_is_full(Y-, L)=TRUE)    return X+;          // X+ direction
  else                                   return Y-;
}

x_route(cx, dx){
  dist_x = (N+dx-cx)%N;
  if(1≦dist_x ≦N/2)                      return X+;
  else                                   return X-;
}

DOR (cx, cy, dx, dy){
  return Link_Select_DOR (cx, cy, dx, dy);
}
```

Fig. 1. Link Selection Function of NSF Algorithm

channel-H is changed to an algorithm that does not necessarily pass the shortest path. The SF routing algorithm after the change is shown in Fig. 2. The big difference between before and after improvement is that adaptive routing that selects both the - direction and the + direction is performed in the horizontal direction (X direction). This enables routing that avoids congestion and failure regardless of whether it is the shortest route or not.

```
// Link Selection Function for NSF-IP Algorithm
adaptive_SF(cx, dx){
  if(buffer_is_full(Y+,H)=FALSE)
        return Y+;
  else if(cx==0) return X+;
  else if(cx==N-1) return X-;
  else return x_adaptive(cx, dx);
}

x_adaptive(cx, dx){
  dist_y = (N+dx-cx)%N;
  if(1<= dist_x <= N/2){
    if(buffer_is_full(X+,H)=FALSE)
        return X+;
   else      return X-;
    }
    else {
        if(buffer_is_full(X-,H)=FALSE)
    return X-;
    else      return X+;
    }
}
```

Fig. 2. Link Selection Function of NSF-IP Algorithm

IV. Evaluation of Congestion Resistance

A communication experiment was conducted with a software simulator that transmits 50000 cycles of packets for a 16 × 16 torus network with 256 PEs and shows the evaluation results. Evaluation by uniform communication pattern was carried out using this simulator. The uniform communication pattern is a simulation performed randomly for both the start point and the end point when sending a packet. Fig. 3 shows the average transfer time for network throughput obtained by simulation. The horizontal axis of the graph is throughput, and the vertical axis is average transfer time. As shown in Fig. 2, it was revealed that the NSF-IP algorithm has a higher throughput than the dimension-order (DOR) algorithm compared with the NSF algorithm. In addition, when the NSF-IP and NSF algorithms were compared, the throughput was almost the same, and no significant performance degradation was observed by improvement. In a communication pattern in which the interconnection network is crowded as a whole like random communication, the effect of avoiding congestion is limited by adaptive routing in an algorithm that does not use additional virtual channels such as that of the turn model.

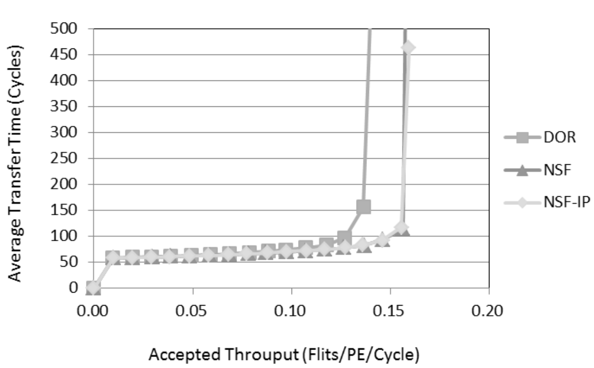

Fig. 3. Results for Uniform Traffic

V. Evaluation of Fault Tolerance

Fault-tolerant performance was evaluated by creating a faulty PE in a 16 × 16 2D torus network simulator with 256 PEs and by communicating. One PE out of 256 PEs was assumed to be a failed PE. In the communication method, communication in which each PE communicates in a form in which each PE randomly handles a packet to each PE 1 to 1 is regarded as one communication, and 255 packets are transmitted at a time. In accordance with the above method, measurement of the number of non-arrival packets for the three algorithms of DOR, NSF, and NSF-IP were made by taking the average of 10 results for 1, 3, and 5 loops for each algorithm. The average number of non-arrival packets is plotted in Fig. 4.

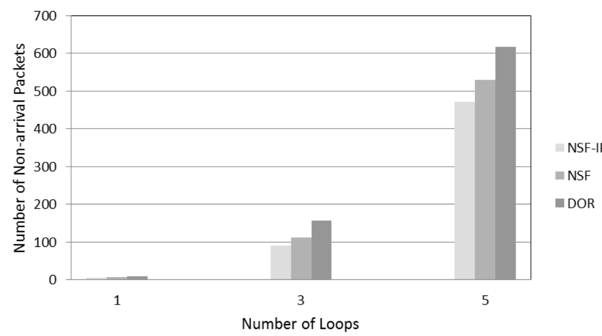

Fig. 4. Plot of Number of Non-arrival Packets

VI. Conclusion

In this paper, an improved NSF algorithm called NSF-IP was proposed as an adaptive routing algorithm applicable to a 2D torus on the basis of the turn model. Congestion resistance and fault tolerance were simulated and evaluated, and the following was clarified. For congestion resistance in the uniform communication pattern, it became clear that the throughput of the NSF and NSF-IP algorithms were improved compared with that of DOR. There was no difference in performance between the NSF algorithm and the NSF-IP algorithm. As for the evaluation of fault tolerance assuming a faulty PE, it was revealed that the packet arrival rate rose in the order of the DOR and NSF algorithms and the NSF-IP algorithm proposed in this paper, and the fault tolerance was excellent.

References

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