Intelligent LoRa NoC Applied in the Environmental Protection for Mu Us Desert

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Abstract. Intelligent NoC can be applied in the filed of environmental protection, since routing algorithm and network architecture possess advantages of speed and capacity. In this paper, wireless LoRa network is attempted to build for the environment of Mu Us Desert on the borders of Shaanxi and Inner Mongolia. Environmental sensors connected to LoRa network collects the environmental information, while intelligent routing algorithm helps to propagate and decide the environmental status. The intelligent NoC can contribute to complex data decision and build the NoC through multicast mapping.

1. Intelligent NoC Routing Algorithm
For the on-chip network architecture, the performance of NoC highly depends on the flexibility of routing algorithms, such as adaptiveness, load balance and multicast mapping. Since routing algorithm decides the connection and path for on-chip communication, the efficiency of NoC mainly depends on the flexibility and performance of applied routing algorithm. In the field of intelligent NoC, intelligent strategies are applied to flexible routing algorithms for specific on-chip design[1].

Adaptiveness of routing algorithm is the ability to adjust propagation path according to network status. Load balance is the measurement for path adjustment, according to light-loaded priority, the adaptive routing algorithms can balance the load of varied regions. The quality of load balance can determine the quality of NoC directly. For massive on-chip data, multicast mapping is employed to cooperate complex information in forms of packets. For parallel NoC architecture, multicast packets can benefit from energy saving and efficient propagation. The intelligent chip demand for adaptiveness and load balance with more advanced decisions, which can adapt to varied situations. For intelligent NoC design, the decisions of routing algorithm based on network connection plays the most important role[2].

The intelligence of NoC is mainly reflected in the fields of routing algorithms, since routing algorithms in good conditions of adaptiveness and load balance can collect sufficient direction information and load information for packet propagation, and in turn decide optimized routing path inside the chip. This collection-decision system can supply intelligent chip for fields of urban facilities, agriculture product and human fitness. In this paper, we propose a sort of adaptive routing for wireless NoC applied in the environmental protection for desert region.
2. Environmental Protection for Mu Us Desert and LoRa Network

2.1. Demand for Environmental Protection
Mu Us Desert locates on the borders of Shaanxi and Inner Mongolia, its southeastern edge stretches across 5 counties of Yulin, Shaanxi[3]. To measure the environmental protection demand of Mu Us Desert, temperature, humidity, wind power and vegetation coverage are the main indicators on certain environmental protection observation point. Varied environmental data containing complex indicators above can be collected by specific sensors. The sensors to collect complex environmental data can form wireless network for NoC to complete on-chip procedure to analyze the environmental conditions and decide protection strategies for Mu Us Desert.

Intelligent NoC can be applied in the environmental protection of Mu Us Desert with the auxiliary of wireless sensor network. The parallel network topology and router technique transplanted from computer network can propagation massive packets including multicast environmental indicators, while the NoC applied for environmental protection intelligent routing algorithm with adaptiveness and load balance[4]. By forming intelligent network and multicast mapping chips, collection network for complex environmental information can be applied to build NoC, with intelligent routing algorithm and multicast mapping[5]. LoRa is applied to connect sensors and to form information propagation network, since LoRa can realize long-distance propagation in open fields such as Mu Us Desert. Figure 1 shows the relationship between the LoRa network and multicast mapped NoC[6].

![Fig. 1 LoRa network and multicast mapping NoC](image)

2.2. Environmental Protection NoC based on LoRa
The intelligent NoC for environmental protection consists of modules below: intelligent routing algorithm, LoRa sensor network and multicast mapping NoC[7].

Intelligent routing algorithm aims at to optimize multicast information and decide optimized routing path, routing algorithm with adaptiveness and load balance is required to deal with complex environmental data efficiently. The adaptiveness can be designed by routing paths selected with lightest load and least congestion[8]. LoRa sensor network can be applied in Mu Us desert as wireless communication backbone since its connecting distance can be up to 20km, intelligent adaptive routing algorithm can be realized on the platform build by LoRa connection and wireless sensor network. Furthermore, Multicast Mapping to realize chips is employed to complete the NoC design for sensor network and multicast detected environmental data[9].

3. Routing Algorithm Design
In this paper, to balance network load, we propose an arbiter that can grant routing path fairly among directions with equal load. To guarantee fairness, the granting principle of proposed fair arbiter with alterable priority (APA)[10] is shown in Table 1, its alternated priority order is adjusted according to
the increasing of defined pointer value, this alteration plays a role to grant each requested direction evenly. As the variation of priority order in Table 1 can evenly grant all the 4 requests, the alternated arbiter can guarantee the routing algorithm with sufficient fairness; thus, APA is proposed as a fair path decision for load-balanced NoC. With APA applied to congestion-aware odd-even(OE) routing algorithm, both adaptiveness and load balance can be improved.

| Status | Pointer | Priority order | Granting mechanism |
|--------|---------|----------------|--------------------|
| 3      | 4n      | 3210           | g3= r3; g2= r3 r2; g1= r3 r2 r1; g0= r3 r2 r1 r0 |
| 2      | 4n+1    | 2301           | g2= r2; g3= r2 r3; g0= r2 r3 r0; g1= r2 r3 r0 r1 |
| 1      | 4n+2    | 1032           | g1= r1; g0= r1 r0; g3= r1 r0 r3; g2= r1 r0 r3 r2 |
| 0      | 4n+3    | 0123           | g0= r0; g1= r0 r1; g2= r0 r1 r2; g3= r0 r1 r2 r3 |

To compare the fairness of APA and conventional round-robin(RR) arbiter, the standard deviation is employed to measure each granted requests according to the difference among the granted ratio and average ideal granting. As compared in Figure 2, among the ratios of all granted requests, the APA can achieve lower standard deviation indicating better fairness than the RR arbiter that conventional considered as the fairest granting. Thus, APA can be a solution to load-balanced adaptive routing algorithm for more optimized decision. In the field of intelligent path decision, fair arbiter can produce optimized connection.

Based on fair routing decision, the flowchart congestion-aware(CA) routing applying APA named congestion-aware OE turn model with fair arbiter(CAOE-FA) is depicted in Figure 3. For the directions permitted according to the OE turn model represented by d1, d2, the CAOE-FA can compare their load level according to the flowchart and select the light loaded d1 or d2 as the routing algorithm output. This decision can provide optimized network load with packets delivered in light loaded regions. Nevertheless, in the scenarios of directions d1, d2 sharing the same congestion index(CI) level according to the lower part of Figure 3, the fairly-granting APA is employed to grant the equally loaded output fairly to produce load-balanced routing algorithm, instead of conventionally random selection without arbitration. In this case, the decision of routing algorithm is made by both light-loaded priority congestion level and load balance arbitration.
4. Result Analysis

The performance matrix of the CAOE-FA routing are shown in Figure 4 and Figure 5 to analyze the load balance of intelligent NoC, with average packet latency indicating speed level and saturation throughput indicating capacity of network respectively. Compared to congestion-oblivious OE turn model or routing schemes without fair arbiter(random selection), the proposed CAOE-FA possesses the lowest average packet latency indicating fastest routing speed and the highest saturation throughput indicating largest data capacity. Under hotspot traffic patterns which can be encountered more often under multi-cast environment protection data collection, with the introducing of fairly granting arbiter APA, the routing algorithm CAOE-FA can lead to improvements of reduced latency shown in in Figure 4 and improved throughput shown in Figure 5, which turns out to be an optimized network scheme compared to congestion-oblivious routings and the randomly selected direction, indicating improvements in speed and capacity that forms more flexible multi-cast connection.
The improved CAOE-FA performance results from flexible intelligent routing algorithm. Based on the routing algorithm, designed NoC can achieve intelligent environment protection data for complex demand through multicast mapping.

5. Conclusion
Footnotes should be avoided whenever possible. If required they should be used only for brief notes that do not fit conveniently into the text.

Acknowledgments
Financial support from: PhD’s research start-up fund BS201937.

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