Design and implementation of an FPGA-based NoC for Real Time Systems

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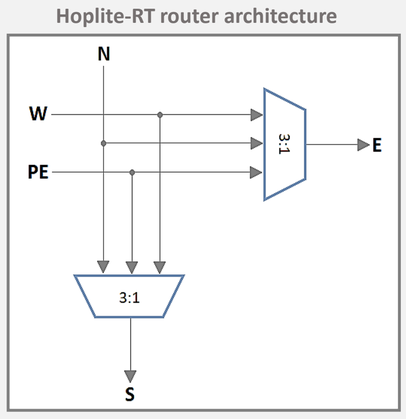
Motivation

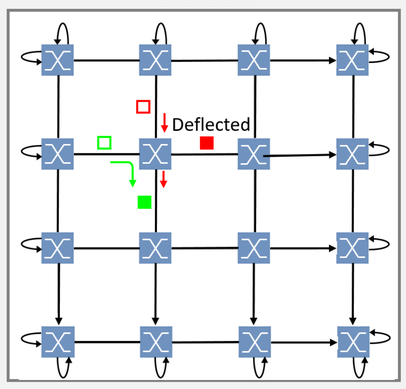
- Most of the **NoC designs** found in the literature are **expensive** to implement in FPGA platforms and their complexity renders their **analysis** very **complex**.
- **Hoplite-RT** is a **new buffer-less NoC design** based on the notion of **deflection** (see below) with **bounded packet WCTT**. However, the **WCTT** may become **large** as the number of deflections grows.
- Hoplite-RT **does not** allow to **associate** different **priorities** to packets, and hence quality of services.

Background on Hoplite-RT[1]

Hoplite-RT router architecture



Hoplite-RT network topology + example of deflection



Network topology: **Unidirectional torus**
Routing policy: Variant of **X-Y routing**

- If two packets coming from the West and North ports **conflict for the South port**, the North packet is **deflected** toward **to the East port**.
- A packet suffers at most **one deflection after each hop on the Y-axis.**

$$wc_{TT} = \underbrace{h_x}_{\text{Distance travelled by the packet on the X-axis}} + \underbrace{h_y}_{\text{Distance travelled by the packet on the Y-axis}} + (h_y \times \underbrace{S_x}_{\text{Number of routers on the X-axis}}) + 2$$

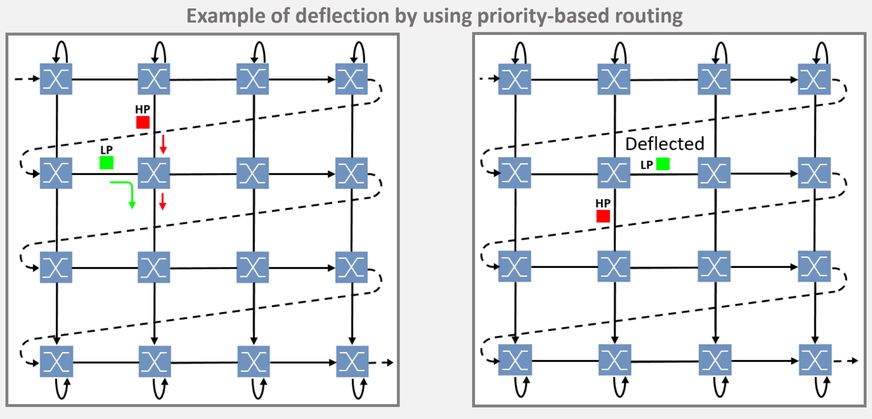
$$h_x = (\underbrace{x_d}_{\text{X coord. of the destination router}} - \underbrace{x_o}_{\text{X coord. of the origen router}} + S_x) \mod S_x$$

$$h_y = (\underbrace{y_d}_{\text{Y coord. of the destination router}} - \underbrace{y_o}_{\text{Y coord. of the origen router}} + S_y) \mod \underbrace{S_y}_{\text{Number of routers on the Y-axis}}$$

Priority-based routing

- A two-priority level (Low and High) scheduling scheme.
- Each packet priority is encoded in its most significant bit.

Example of deflection by using priority-based routing



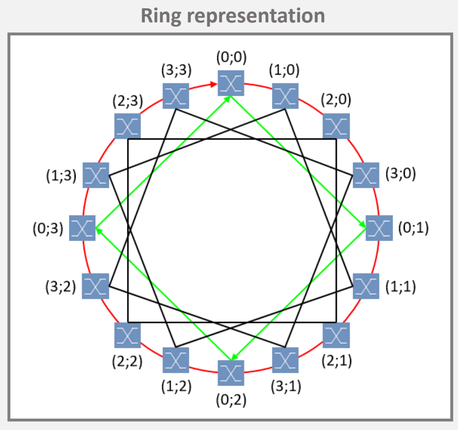
WCTT of high priority packets is independent from low priority packets.

Contributions

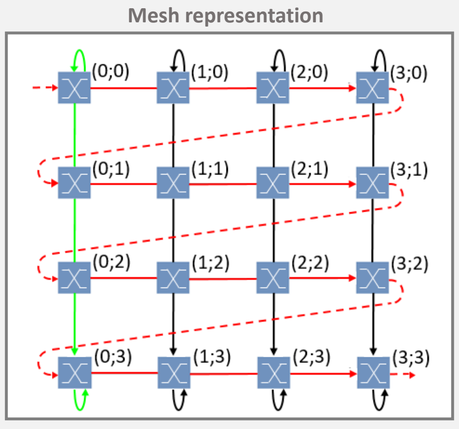
New network topology

- **Unidirectional ring with bypasses**.
- Packets always **move towards** their **destination**.

Ring representation



Mesh representation



WCTT of low priority packets remain bounded.

New WCTT bound

$$wc_{TT} = \underbrace{n_{hops}}_{\substack{\text{Number of hops in a network with zero load}}} + \underbrace{n_{def}}_{\substack{\text{Maximum number of deflections}}} \times \underbrace{c_{def}}_{\substack{\text{Cost of a deflection}}}$$

- Number of hops in a network with zero load

$$n_{hops} = \underbrace{h_r}_{\text{Number of hops on the ring}} + \underbrace{h_b}_{\text{Number of hops on the bypasses}} + 2$$

$$h_r = (x_d - x_o + S_x) \mod S_x$$

$$h_b = (y_d - \underbrace{y'_o}_{\substack{\text{Y coord. of the router at which the packet stops travelling on the ring and starts using bypasses}}} + S_y) \mod S_y \qquad y'_o = \begin{cases} y_o, & x_d \geq x_o \\ y_o + 1, & x_d < x_o \end{cases}$$

- Maximum number of deflections

For high priority packets $\Big\}$ $n_{def} = \left\lfloor \frac{h_b}{2} \right\rfloor$ *For low priority packets* $\Big\}$ $n_{def} = h_b$

- Cost of a deflection

$$c_{def} = S_x - 1$$

In most cases, the WCTT of high priority packets is divided by two and the WCTT of the low priority packets does not exceed that of the original Hoplite-RT.

Resources utilization

Router	LUTs	FFs
Hoplite-RT router	85	139
Hoplite-RT router + Priorities	86	139
Hoplite-RT router + Priorities + New network topology	88	139

Very limited additional hardware cost.

References

[1] S. Wasly, R. Pellizzoni, and N. Kapre, "HopliteRT: An efficient FPGA NoC for real-time applications," in 2017 International Conference on Field Programmable Technology (ICFPT), Dec 2017, pp. 64–71.

Future work

- We plan on developing solutions to ensure that packets received at the destination router are received in the same order as they were emitted at the origin router.
- We are also working on solutions to map applications on nodes and configure packet injection rates at each node.

Co-financed by Unidade de I&D CISTER - CEC/04234
FCT Fundação para a Ciência e a Tecnologia

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