ECE 695R: System-on-Chip Design

Module 5: Networks-on-chip
Lecture 5.8: Flow Control Mechanism

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What characterizes an NoC?

- **Topology**
  - physical interconnection structure of the network graph

- **Routing Algorithm**
  - restricts the set of paths that messages may follow
  - many algorithms with different properties

- **Switching Strategy**
  - how data in a message traverses a route
  - circuit switching vs. packet switching

- **Flow Control Mechanism**
  - when a msg or portions of it traverse a route
  - what happens when traffic is encountered?
Flow control

In buffered switching, it determines the way the downstream node communicates buffer availability to the upstream node.

- ACK-NACK Flow control
- ON-OFF Flow control
- Credit based Flow control
ACK-NACK Flow control

- Transmission
- ACK and buffering
- NACK

- ACK/NACK propagation
- Memory deallocation
- Retransmission
- Go-back-N

- Makes optimistic assumptions for transmission
  ■ Latency gains vs Bandwidth inefficiency in case of congestion
- Long buffer occupancy at the upstream
- Natively supports link-level error control
Credit based flow control

- Large amount of upstream signaling (e.g., short packets)
- Error control pushed to a higher layer

Receiver gives $N$ credits to sender
- **Sender decrements count**
- **Stops sending if zero**
- **Receiver sends back credit as it drains its buffer**
- **Bundle credits to reduce overhead**
On-Off flow control

• Potentially reduces the amount of upstream signalling
• Upstream state: 1 control bit
  – Permission to send (on) or not (off)
  – Upstream signalling only to change this state
Deadlock, Livelock and Starvation

Three reasons why a packet might not reach its destination:

• Deadlock
  – A packet is blocked indefinitely

• Livelock
  – A packet never reaches its destination (misrouting), even if it never gets blocked permanently

• Starvation
  – Some resource does not grant access
Example of **deadlock in wormhole routing**

- Because non-head flits do not contain routing information, they remain in contiguous channels of the network and do not allow any interleaving with the flits of other packets.
- When a cycle is created in the channel dependency graph, the result is a deadlock condition.
- One way to achieve deadlock-free wormhole routing is to assure the absence of cycles in the channel dependency graph.
- Virtual channels are another way to avoid deadlock.

Summary

• NoCs could be viewed as a next step in the evolution of on-chip communication architecture

• Attempt to “scale down” concepts from larger systems (large-scale parallel computers, data communication networks) to SoC context

• Challenges
  – Power
    • Complex NI and switching/routing logic blocks are power hungry
    • Several times greater than for current bus-based approaches
  – Latency
    • Additional delay to packetize/de-packetize data at NIs
    • Flow/congestion control and fault tolerance protocol overheads
    • Delays at the numerous switching stages encountered by packets
    • Even circuit switching has overhead
    • Lags behind what can be achieved with bus-based communication