Formally verified deadlock detection in packet and wormhole networks

NWO free competition 612.064.811

Freek Verbeek, Radboud Universiteit Nijmegen, f.verbeek@cs.ru.nl
Julien Schmaltz, Open Universiteit Nederland, Julien.Schmaltz@ou.nl

Open Universiteit

NWO — Netherlands Organisation for Scientific Research

Radboud University Nijmegen

Deadlock-free routing

- Deadlock freedom is an essential property for Networks-on-chips
- Manual deadlock detection is extremely error-prone
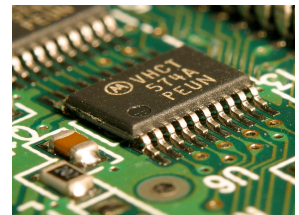
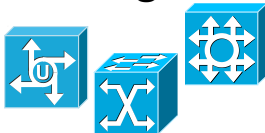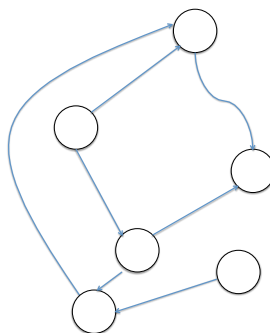| Switching	Complexity	Complete	Formally verified
Packet	$O(N^2)$	Yes	Yes
Wormhole	$O(N^3)$	No	Yes

Algorithms

Network

Routing

Switching policy
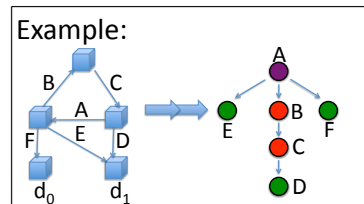- ✓ Packet
- ✓ Wormhole

Resource dependency graph

Markings

Resource r is:

- 🟢 Deadlock-immune
- 🔴 Deadlock-sensitive
- 🟣 Deadlock-attainable
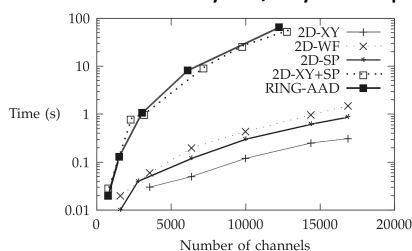
Example:

Results

Implementation of algorithms in C

Topologies:
- Mesh/ring
- Virtual channels

Routing functions:
- Deterministic/adaptive
- Cyclic/acyclic dependencies

Source code and proof scripts:
http://www.cs.ru.nl/~freekver/dl_ic.html

Formal verification

Formally verified:
- Necessary and sufficient conditions
- Correctness of specification of algorithms

ACL 2 — A COMPUTATIONAL LOGIC — APPLICATIVE COMMON LISP

References

- F. Verbeek and J. Schmaltz. A Fast and Verified Algorithm for Proving Store-and-Forward Networks Deadlock-Free (PDP'11)
- ----. Automatic verification for deadlock in networks-on-chips with adaptive routing and wormhole switching (NOCS '11)
- ----. *On Necessary and Sufficient Conditions for Deadlock-Free Routing in Wormhole Networks* (TPDS '11)
- ----. *A Comment on "A Necessary and Sufficient Condition for Deadlock-Free Adaptive Routing in Wormhole Networks"* (TPDS '11)