

Chapter 4: Routing Algorithms



Outline

- **Properties impacted by Routing Algorithms**
- **Taxonomy of Routing Algorithms**
- **Routing Algorithms for Direct Networks**
 - deterministic
 - partially-adaptive
 - fully-adaptive
- **Routing in MINs**
- **Routing in Irregular Networks**

Properties impacted by Routing

- **Connectivity**
- **Adaptivity**
- **Deadlock and Livelock Freedom**
- **Fault-tolerance**

Taxonomy of Routing Algorithms

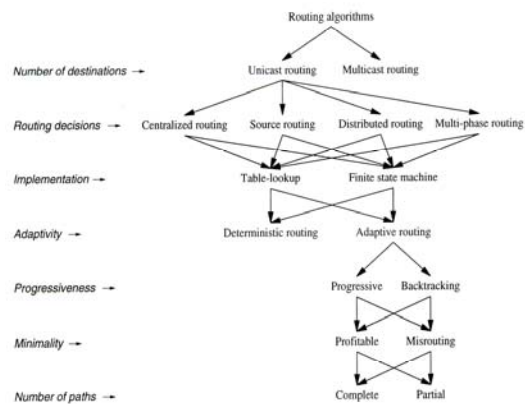


Figure 4.1: A taxonomy for routing protocols

Deterministic Routing

Algorithm: XY-Routing for 2-D Meshes
Inputs: Coordinates of current node ($X_{current}, Y_{current}$)
and destination node (X_{dest}, Y_{dest})
Output: Selected output *Channel*
Procedure:
 $X_{offset} := X_{dest} - X_{current};$
 $Y_{offset} := Y_{dest} - Y_{current};$
if $X_{offset} < 0$ **then**
 $Channel := X-;$
endif
if $X_{offset} > 0$ **then**
 $Channel := X+;$
endif
if $X_{offset} = 0$ and $Y_{offset} < 0$ **then**
 $Channel := Y-;$
endif
if $X_{offset} = 0$ and $Y_{offset} > 0$ **then**
 $Channel := Y+;$
endif
if $X_{offset} = 0$ and $Y_{offset} = 0$ **then**
 $Channel := Internal;$
endif

Figure 4.3: The XY-routing algorithm for 2-D meshes

X-Y/E-cube Routing

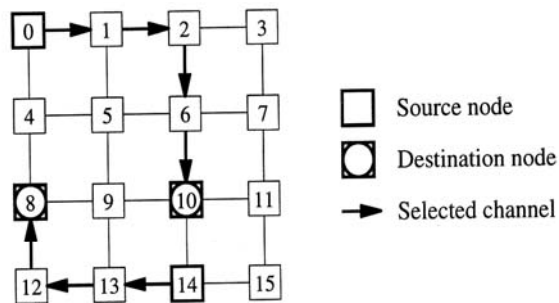


Figure 4.2: Routing example for dimension-order routing on a 2-D mesh

Routing in Ring/Tori

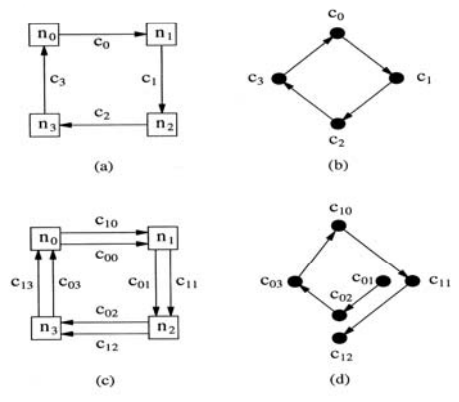


Figure 4.5: Unidirectional rings and their channel dependency graphs

Partially-Adaptive (Planar)

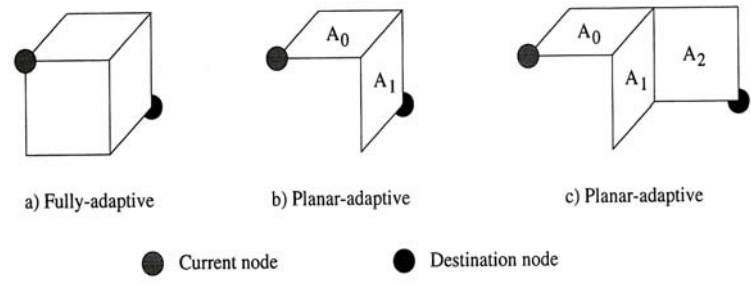


Figure 4.7: Allowed paths in fully-adaptive and planar-adaptive routing

Planar-Adaptive

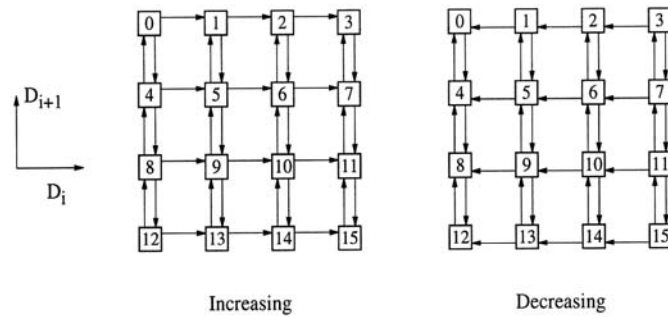


Figure 4.8: Increasing and decreasing networks in plane A_i for planar-adaptive routing

Turn Model

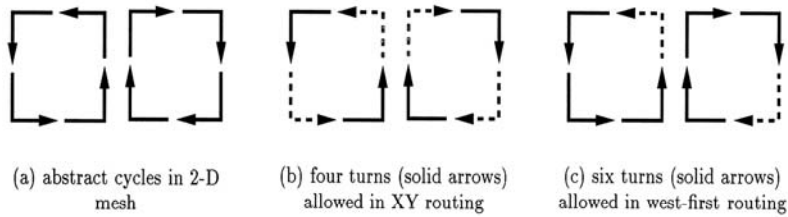


Figure 4.9: An illustration of the turn model in 2-D mesh

West-First Routing

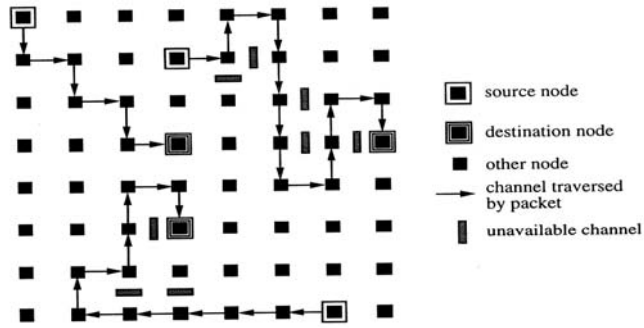


Figure 4.11: Examples of west-first routing in an 8×8 2-D mesh.

Fully-Adaptive/Virtual Network

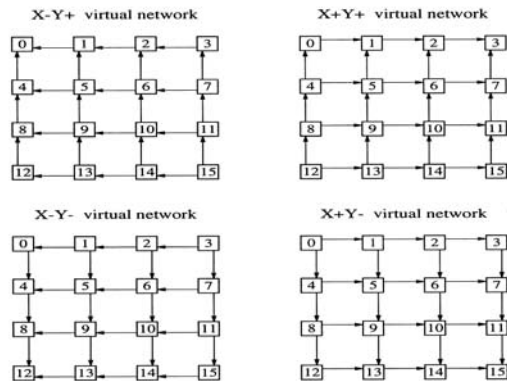


Figure 4.16: Virtual networks for a 2-D mesh

Fully-Adaptive/Duato

- Two kinds of virtual channels (networks)
 - basic
 - additional
- Let R_1 be a routing sub-function on basic channels
 - connected
 - deadlock-free
 - deterministic or adaptive
- A routing function R is fully-adaptive
 - at a node, get routed by additional channels if available
 - if all additional channels are busy, wait on the 'basic' channel(s) according to routing sub-function R_1
- Minimum number of virtual channels
 - 2 (1 basic and 1 additional) for k-ary n-mesh
 - 3 (2 basic and 1 additional) for k-ary n-cube

Routing in MIN/Self-Routing

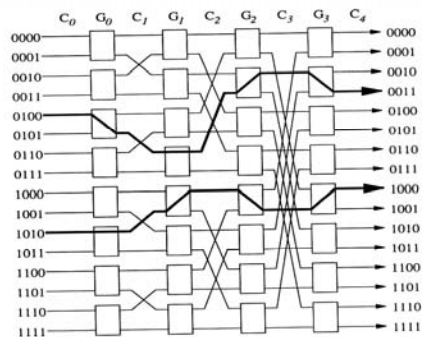


Figure 4.30: Paths selected by the tag-based routing algorithm in a 16-node butterfly MIN

Routing in BMINs

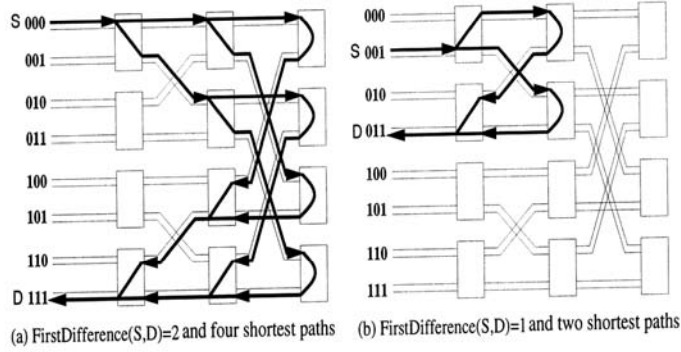


Figure 4.31: Paths available in an 8-node bidirectional butterfly MIN

Routing in Irregular Networks

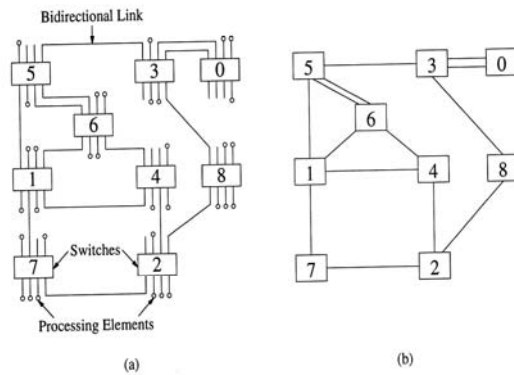


Figure 4.32: (a) An example system with switch-based interconnect and irregular topology; (b) the corresponding graph G

DEC Autonet Routing

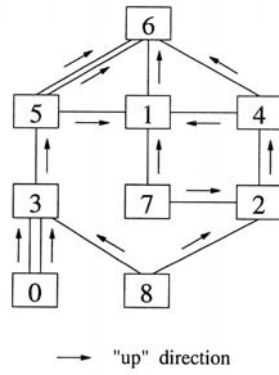


Figure 4.33: BFS spanning tree and link direction assignment