Communication Costs in Parallel Machines

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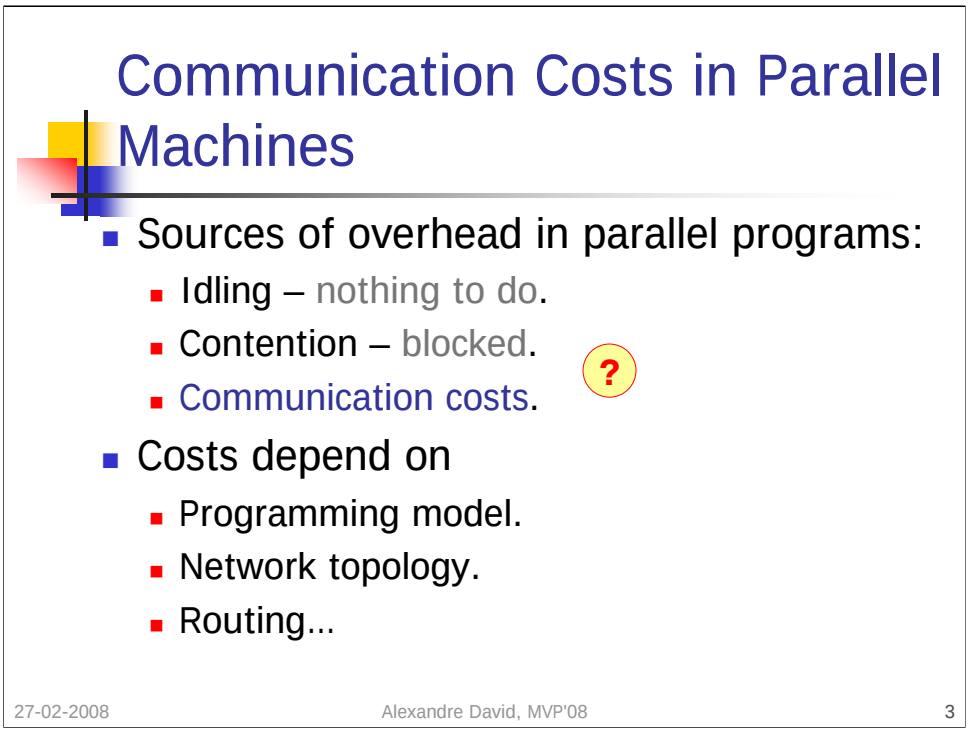
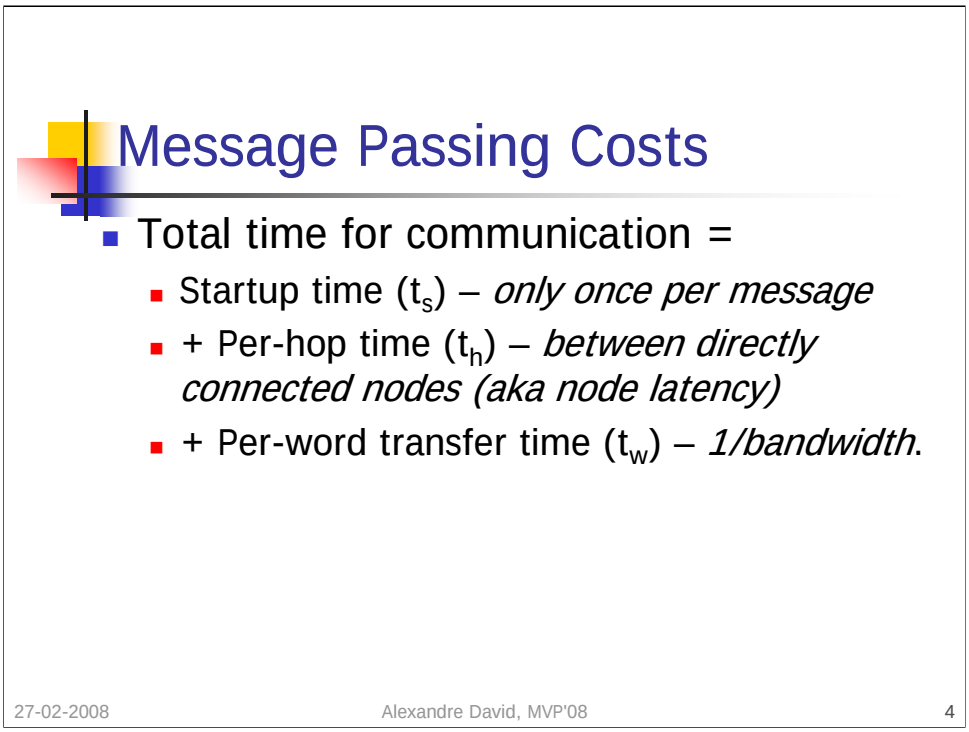
1.2.05

Topics

- Communication Costs in Parallel Machines (2.5)
  - MPI
  - Shared Address Space
- Routing Mechanisms for Interconnection Networks (2.6)



Communication cost is one of the major overheads.

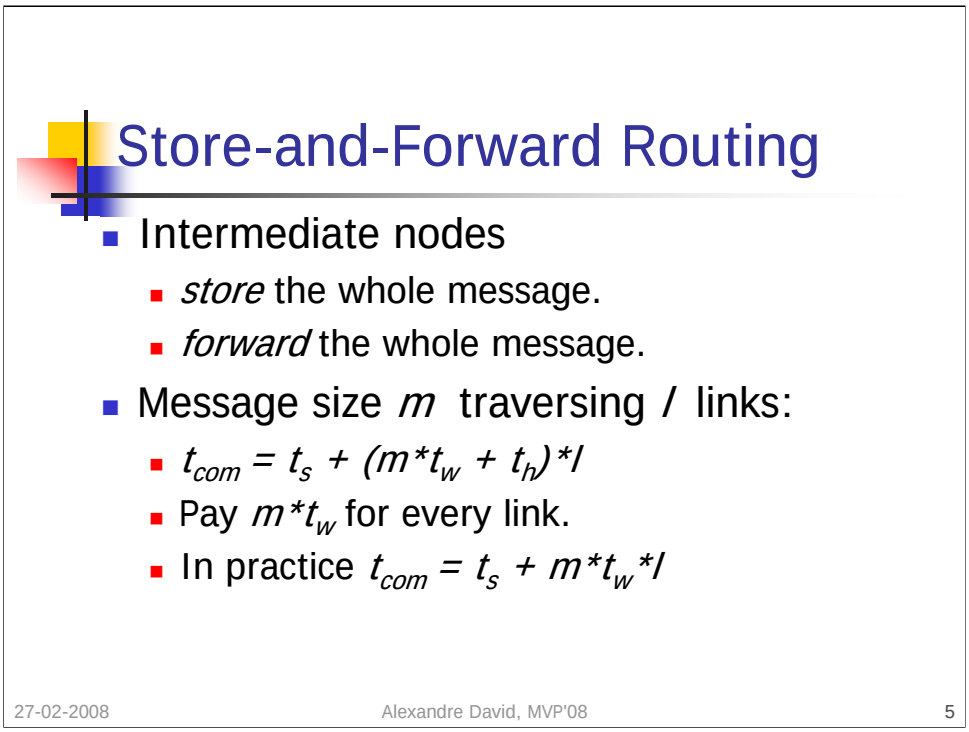


The total time to transfer a message over a network comprises of the following:

•*Startup time* (t_s): Time spent at sending and receiving nodes (executing the routing algorithm, programming routers, etc.).

•*Per-hop time* (t_h): This time is a function of number of hops and includes factors such as switch latencies, network delays, etc. Also known as **node latency**.

•*Per-word transfer time* (t_w): This time includes all overheads that are determined by the length of the message. This includes bandwidth of links, error checking and correction, etc.



Simplify in practice because t_h is small.

Obviously inefficient for long messages!

Packet Routing

- Cut the message in smaller parts.
- Advantages:
  - Lower overhead for errors (less retransmission).
  - More robust routing (different paths for packets, avoid congestion).
  - Better error correction.
  - Better resource utilization (like pipeline).
  - But... more complex protocol.

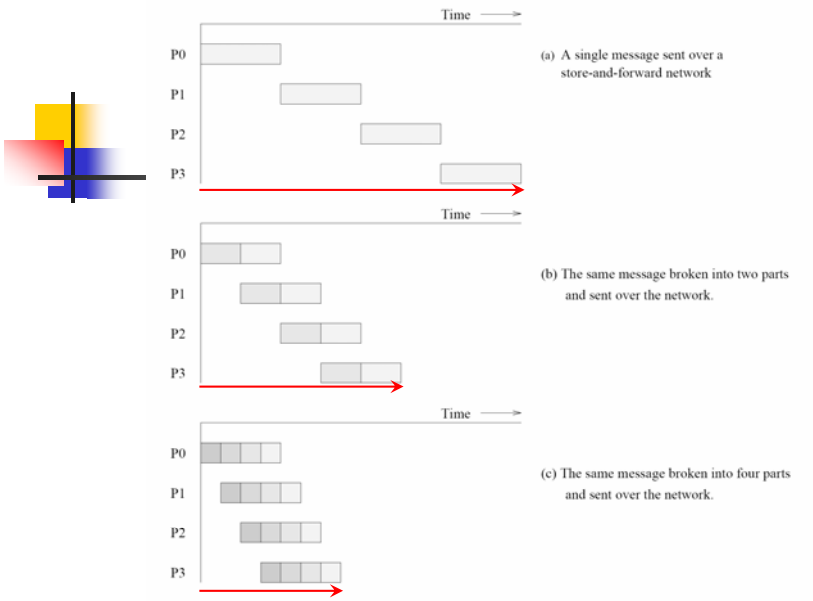
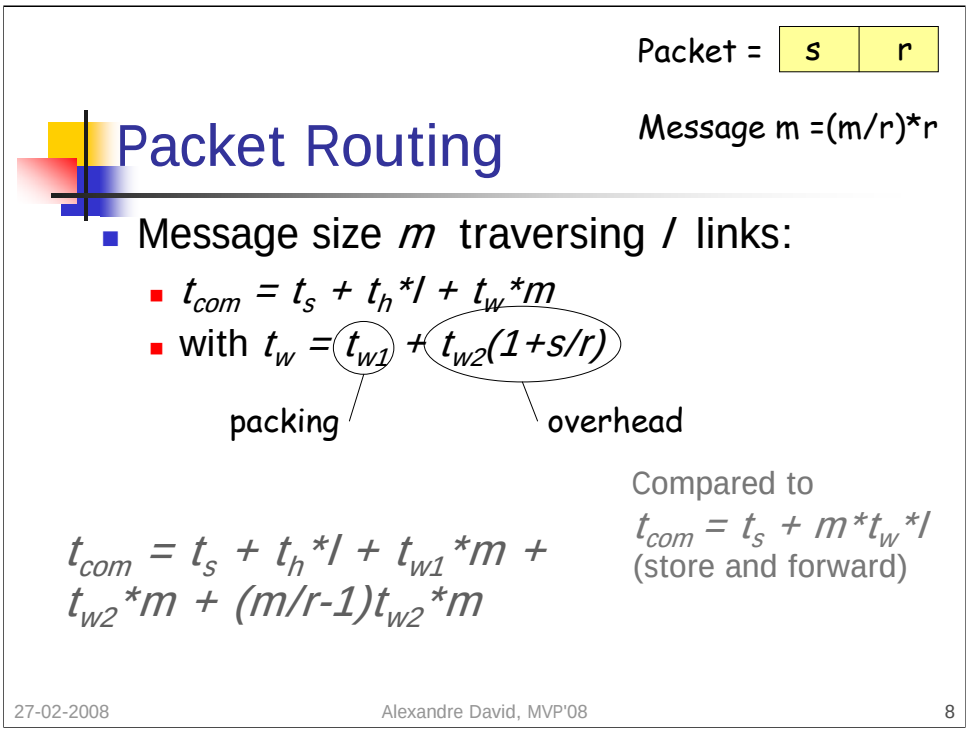


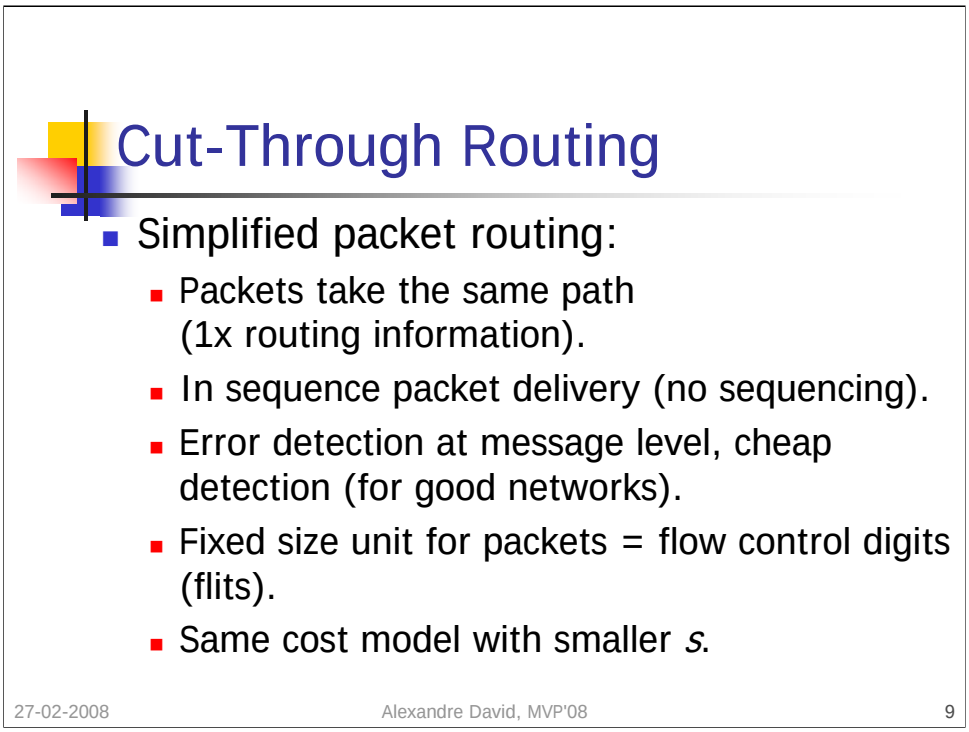
Figure 2.26 Passing a message from node P_0 to P_3 (a) through a store-and-forward communication network; (b) and (c) extending the concept to cut-through routing. The shaded regions represent the time that the message is in transit. The startup time associated with this message transfer is assumed to be zero.

Comparison of store & forward with cutting the message in to 2 and 4 packets.



Approximation here.

Goal is not to remember a bunch of formulas but to understand how to model communication costs.



It is an optimization for interconnection networks of parallel machines since error rates are very low (dedicated network).

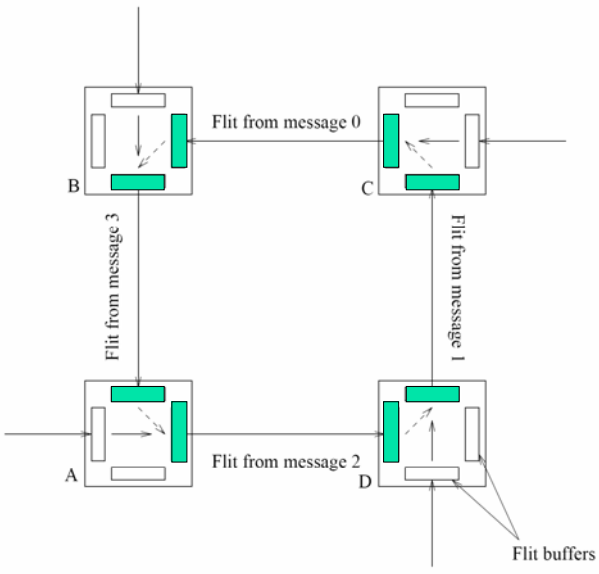
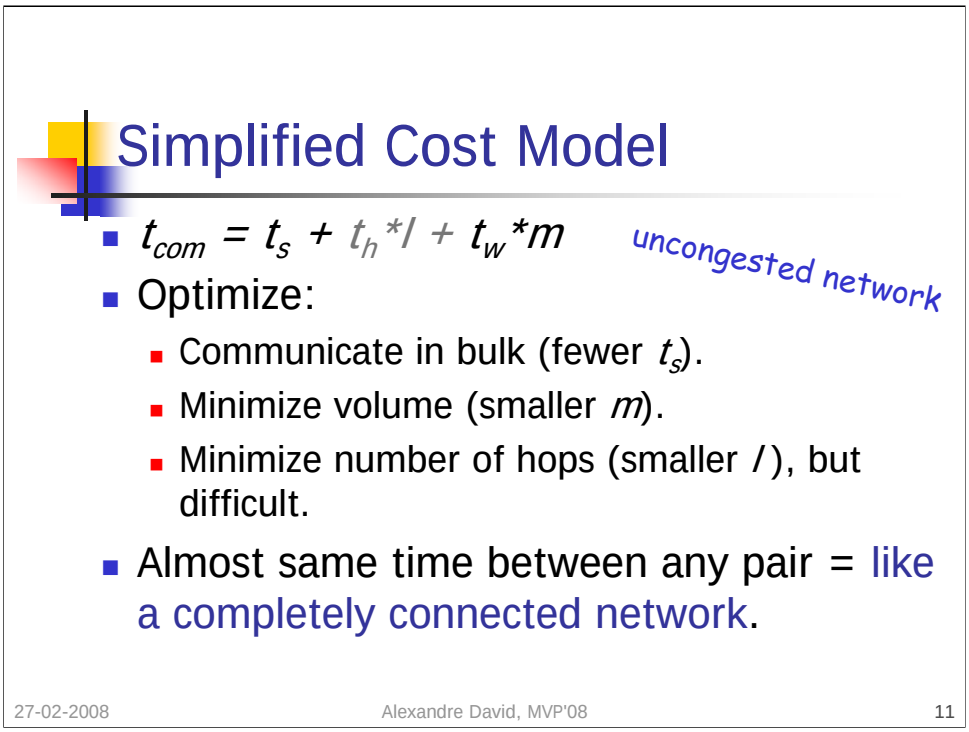


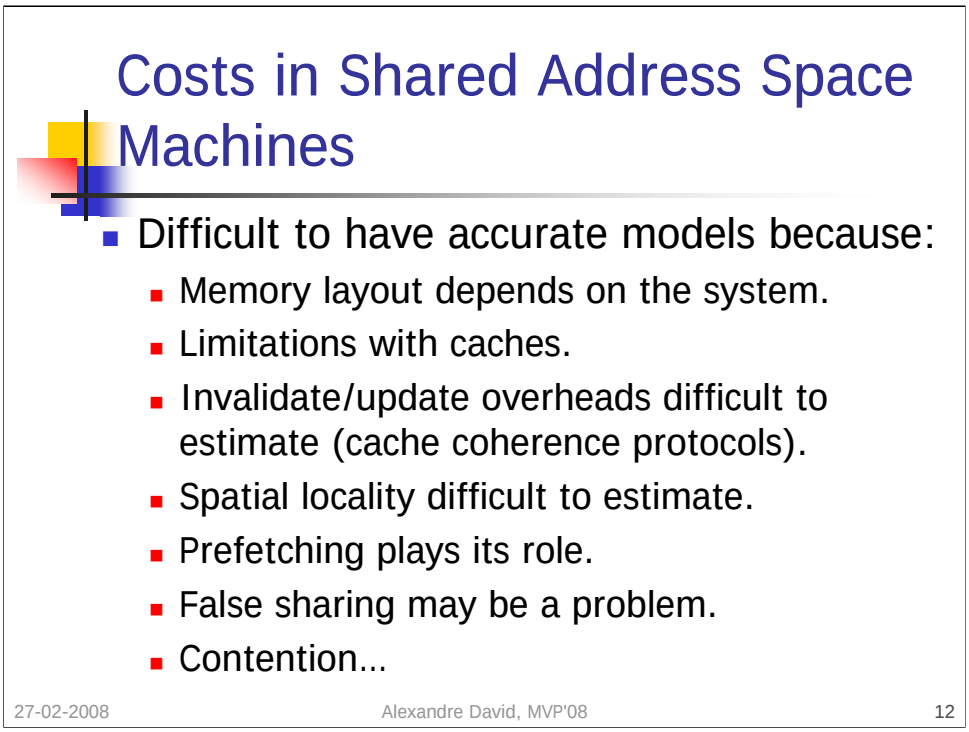
Figure 2.27 An example of deadlock in a cut-through routing network.



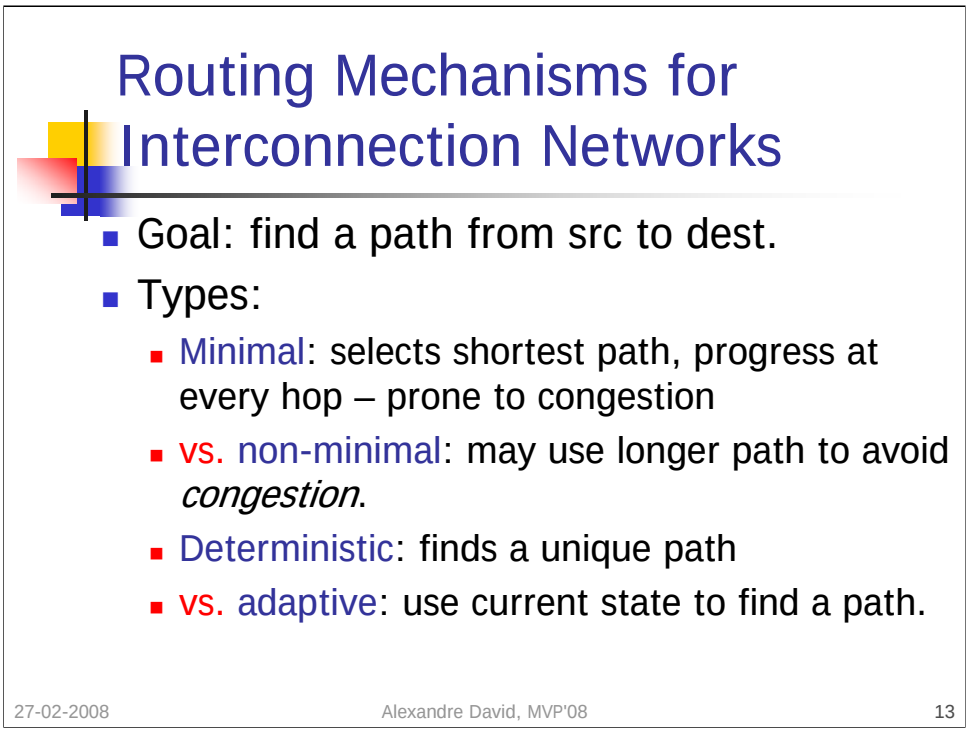
Simplification justified by t_s (in practice) and t_w*m (for algorithm we will see) much larger than t_h*l.

Point 3 difficult because the program has little control over this parameter that is more architecture bound. Can use proximity with a good process-processor mapping.

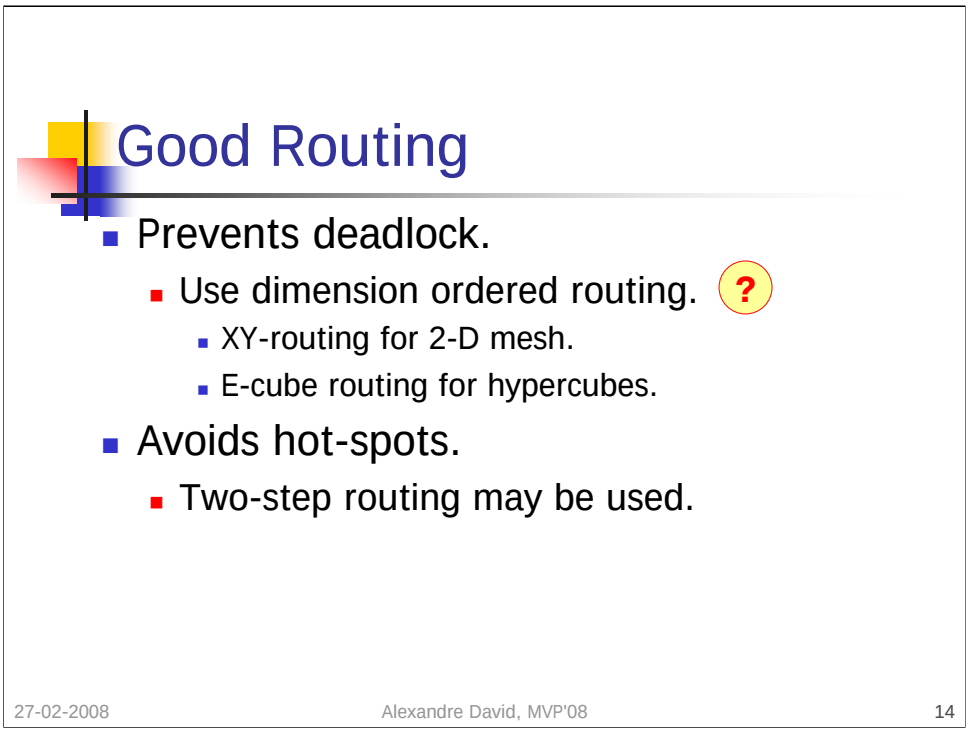
Original expression valid for **uncongested** networks. Communication patterns have an impact on congestion. Incorporate congestion: links have to transport more messages (x), to t_w is affected and it takes x messages more time -> talk about **effective bandwidth** to scale down bandwidth (or scale up transmission time



So, use the same model as before with much smaller t_w (for UMA machine).



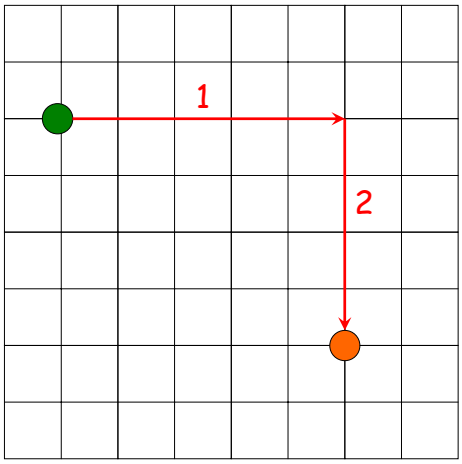
Common issue is congestion.



Deterministic minimal routing commonly used: dimension ordered routing. Use a numbering scheme for channels determined by the dimension.

Two-step routing: 1) choose an intermediate randomly, 2) route.

XY-Routing



Path length =
|Sx - Dx| + |Sy - Dy|

E-Cube Routing

- N-dimension hypercube:
  - Nodes have N neighbors.
  - 2^N nodes.
  - Numbering scheme s.t. change 1 bit along any dimension.
- Routing: progress towards a goal number.

E-Cube Routing

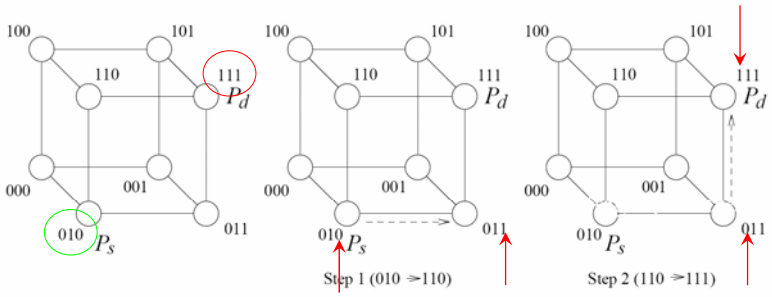


Figure 2.28 Routing a message from node P_s (010) to node P_d (111) in a three-dimensional hypercube using E-cube routing.