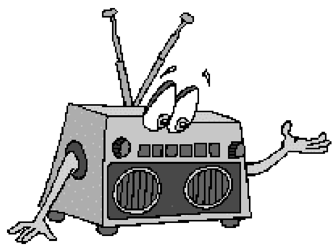
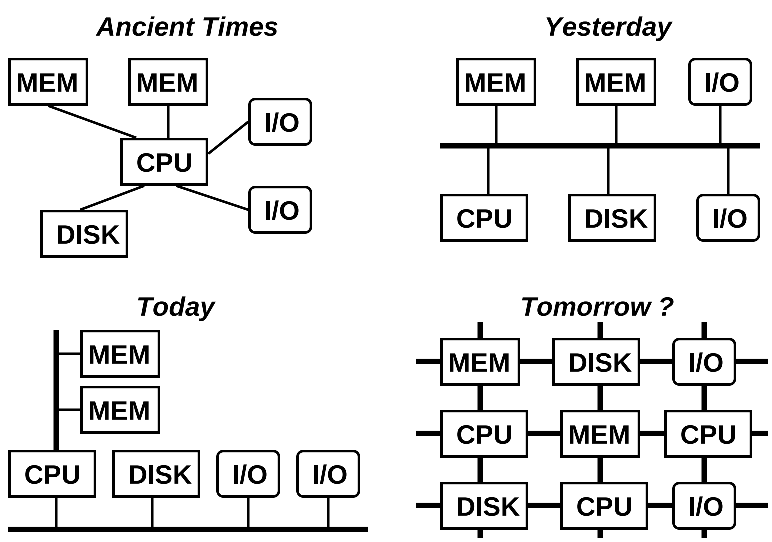
6004 Spring 1998: L49

Communication Technology



1

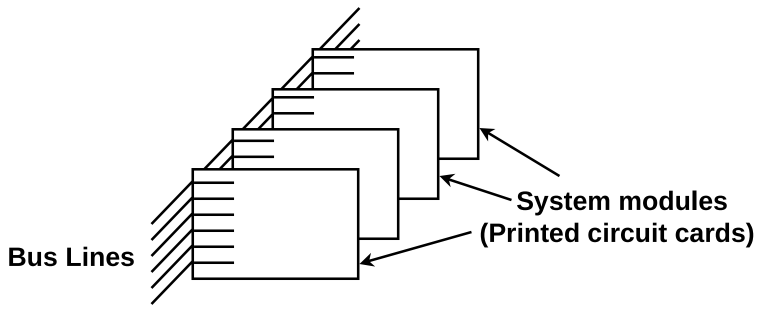
Computer System Communications



2

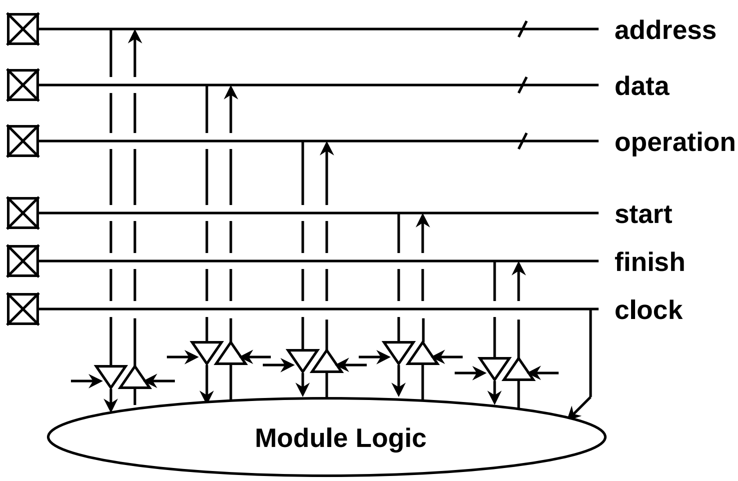
Backplane Bus

- Rigid backplane containing row of connectors
- System modules plug into the connectors
- Logical protocol to avoid electrical conflict
  - Tristate drivers (only 1 driver active at any time)
  - Open-collector technology (passive pullups)



3

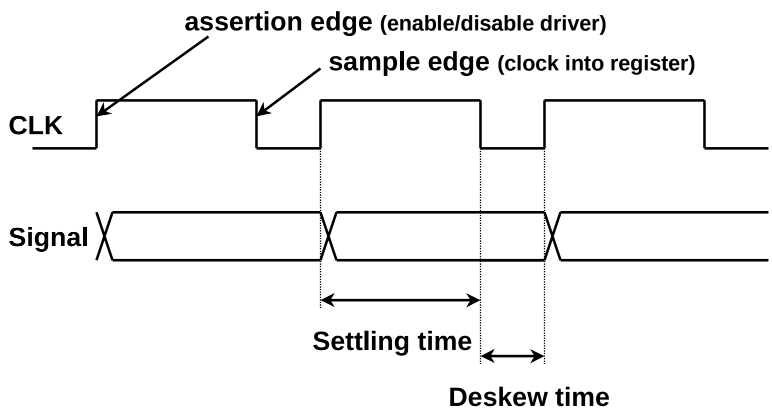
Synchronous Locally Timed Bus Lines



Synchronize start and finish events with clock

4

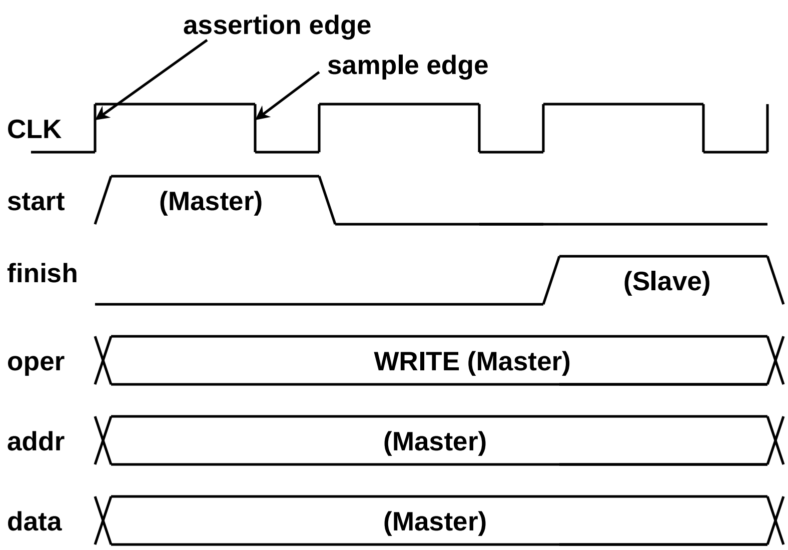
Clock Timing on a Synchronous Bus



Clocking scheme uses two edges to time the transmission and reception of each signal independently.

5

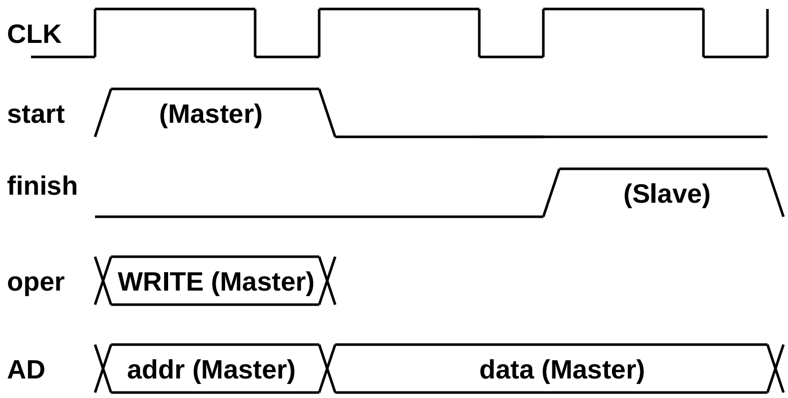
Bus Write Transaction



6

6004 Spring 1998: L49

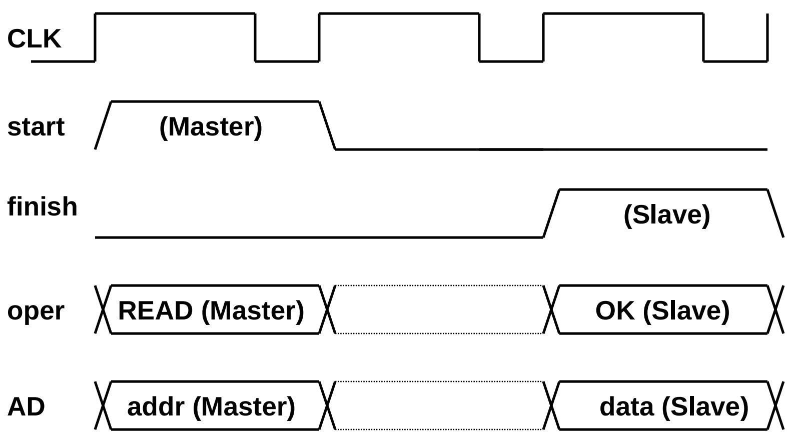
Multiplexed Bus Write Transaction



Throughput = ______

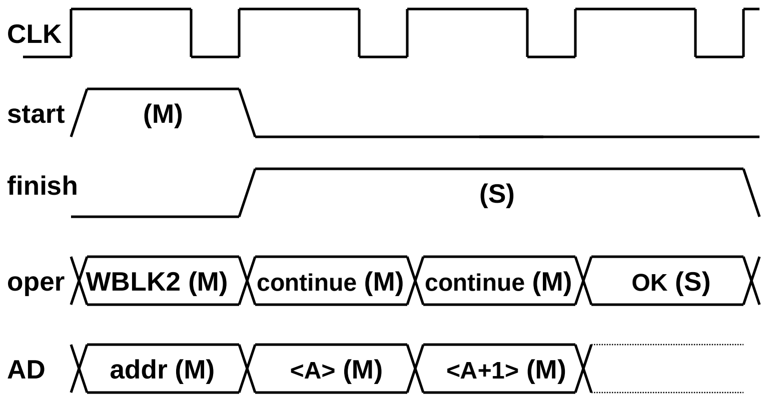
7

Multiplexed Bus Read Transaction



8

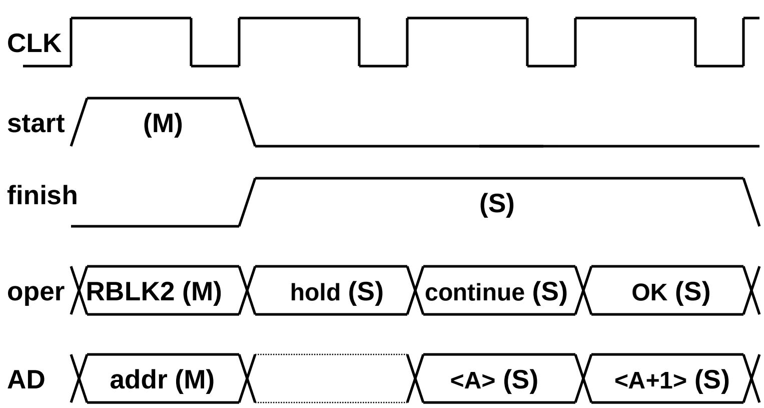
Block-Transfer Write Transaction



Throughput for large block sizes = ______

9

Block-Transfer Read Transaction



10

Bus Arbitration

- **Single module can be designated as the permanent bus master**
- **Modern buses allow bus mastership to change from one transaction to the next**
  - **Some form of arbitration is performed to select, from among participating modules, the master for the next transaction**
- **Many different arbitration schemes exist. Issues are:**
  - **Performance penalty of arbitration**
  - **Hardware complexity**
  - **Fairness: No module gets second cycle until all requesting modules get first cycle**

11

Generalized Communication

Goal: Transfer messages between senders and receivers in a network of interconnected modules

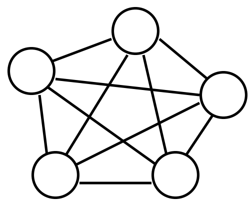
Choices to be made:

- **Point-to-point versus Multicast**
- **Serial versus Parallel**
- **Topology**
  - » **Ring**
  - » **Bus**
  - » **Crossbar**
  - » **Mesh**
  - » **Tree**
  - » **Hypercubes**

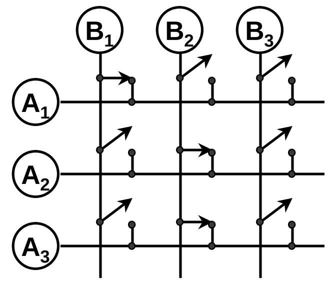
12

Topologies: Graphs and Crossbars

Complete Graph



Crossbar



$\Theta(n)$ simultaneous communications

____ steps for random message delivery

____ hardware cost (wiring)

$\Theta(n)$ simultaneous comm.

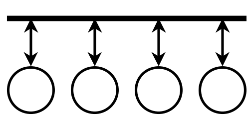
____ steps for random message delivery

____ hardware cost

13

Topologies: Rings and Buses

Bus

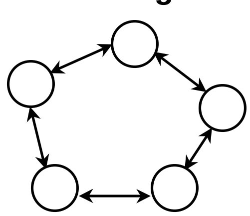


$\Theta(1)$ simultaneous communications

____ steps for random message delivery

____ hardware cost

Ring



$\Theta(n)$ simultaneous communications

____ steps for random message delivery

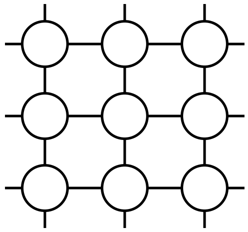
____ hardware cost

14

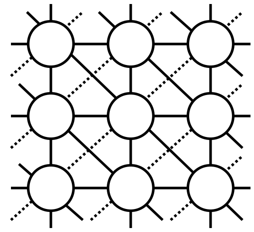
Topologies: Meshes

2-Dimensional Mesh

4 neighbors



8 neighbors



Θ(n) simultaneous communications

____ steps for random message delivery

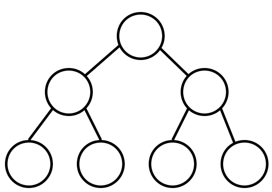
____ hardware cost

(Also 3-Dimensional 6-Neighbor Mesh)

15

Topologies: Trees

Binary Tree



Θ(n) simultaneous comm.

____ steps for random message delivery

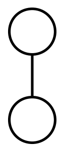
____ hardware cost

Drawback of trees is root congestion.
About half of node-to-node paths go through root.

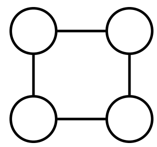
16

Topologies: Hypercubes

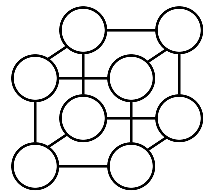
1-Cube



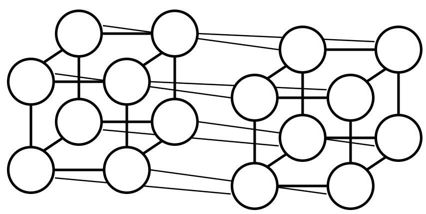
2-Cube



3-Cube



4-Cube



Θ(n) simultaneous comm.

____ steps for random message delivery

____ hardware cost

17

Theoretical Latency of Topologies

Each point-to-point link requires one hardware unit
Each point-to-point communication requires one time unit

Topology	Cost	Latency
Complete graph	$\Theta(n^2)$	$\Theta(1)$
Crossbar	$\Theta(n^2)$	$\Theta(1)$
1-D Bus	$\Theta(n)$	$\Theta(1)$
2-D Mesh	$\Theta(n)$	$\Theta(\sqrt{n})$
3-D Mesh	$\Theta(n)$	$\Theta(\sqrt[3]{n})$
Tree	$\Theta(n)$	$\Theta(\log n)$
N-cube	$\Theta(n \log n)$	$\Theta(\log n)$

18

Real Latencies of Topologies

Speed of light is 1 foot/ns ⇨ Point-to-point communication requires time proportional to distance travelled.

Best we can do is $\Theta(\sqrt[3]{n})$ in a 3-dimensional universe!

Topology	Cost	Latency
Complete graph	$\Theta(n^2)$	$\cancel{\Theta(1)}$ $\Theta(\sqrt[3]{n})$
Crossbar	$\Theta(n^2)$	$\cancel{\Theta(1)}$ $\Theta(n)$
1-D Bus	$\Theta(n)$	$\cancel{\Theta(1)}$ $\Theta(n)$
2-D Mesh	$\Theta(n)$	$\Theta(\sqrt{n})$
3-D Mesh	$\Theta(n)$	$\Theta(\sqrt[3]{n})$
Tree	$\Theta(n)$	$\cancel{\Theta(\log n)}$ $\Theta(\sqrt[3]{n})$
N-cube	$\Theta(n \log n)$	$\cancel{\Theta(\log n)}$ $\Theta(\sqrt[3]{n})$

19