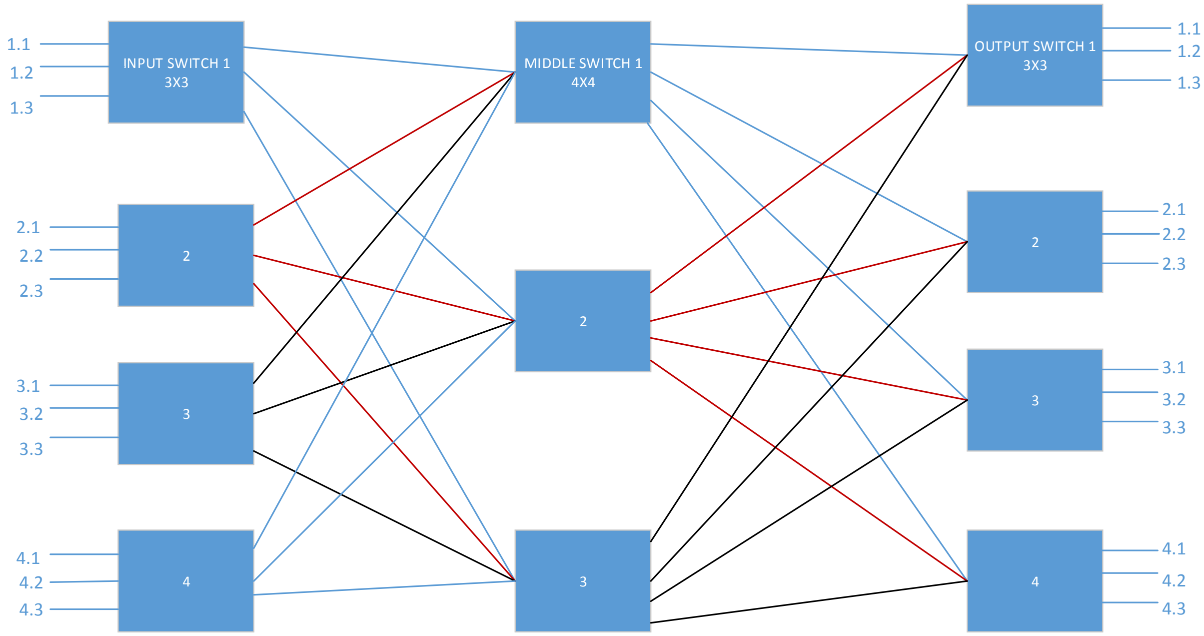
CLOS Networks



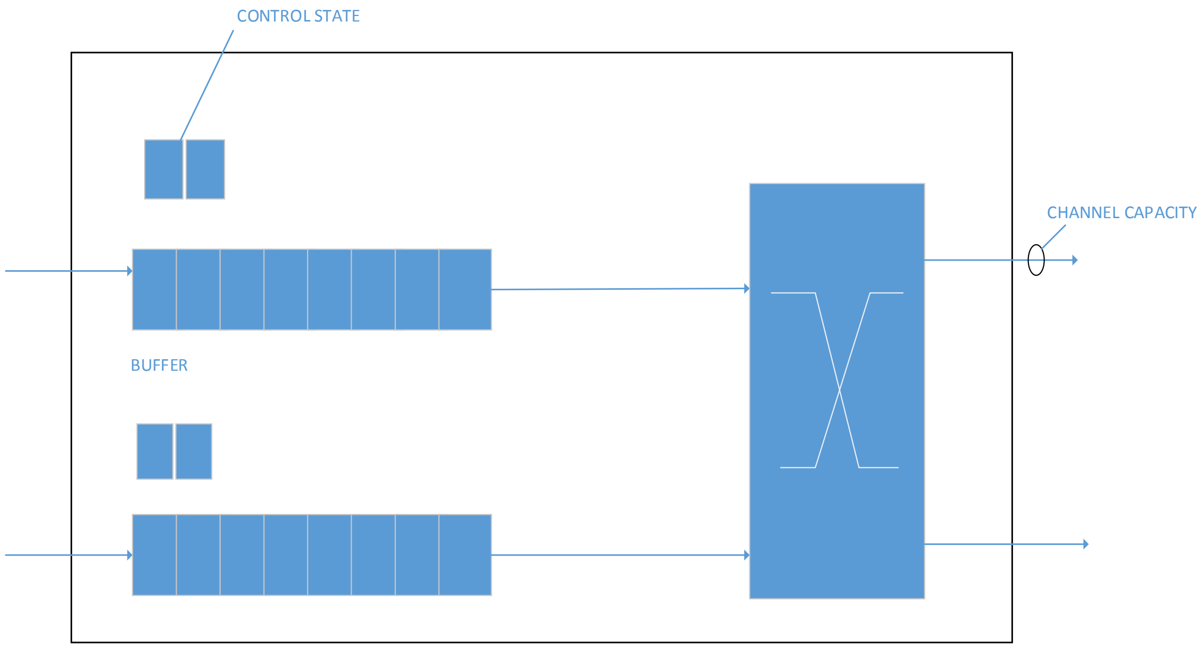
(Figure 1: An (m=3, n=3, r=4) Symmetric CLOS network. All switches are crossbars)

A Clos network is a 3 stage network in which each stage is composed of a number of crossbar switches. A symmetric Clos is characterized by a triple (m, n, r) where m is the number of middle stage switches, n is the number of input (output) ports on each input (output), and r is the number of input and output switches. In a Clos network, each middle stage switch has one input link from every input switch and one output link to every output switch.

FLOW CONTROL

- Flow control determines how a network's resources, such as channel bandwidth, buffer capacity, and control state, are allocated to packets traversing the network
- A good flow control method allocates these resources in an efficient manner, so the network achieves a high fraction of its ideal bandwidth and delivers packets with low predictable latency.
- One can view flow control as either a problem of resource allocation or contention resolution. From the resource allocation perspective, resources in the form of channels, buffers, and state must be allocated to each packet as it advances from the source to the destination. The same problem can be viewed as one of resolving contention. For example, two packets arriving on different inputs of a router at the same time may both desire the same output. In this situation, the flow control mechanism resolves this contention, allocating the channel to one packet and somehow dealing with the other, blocked packet.

Interconnection Networks: Resources

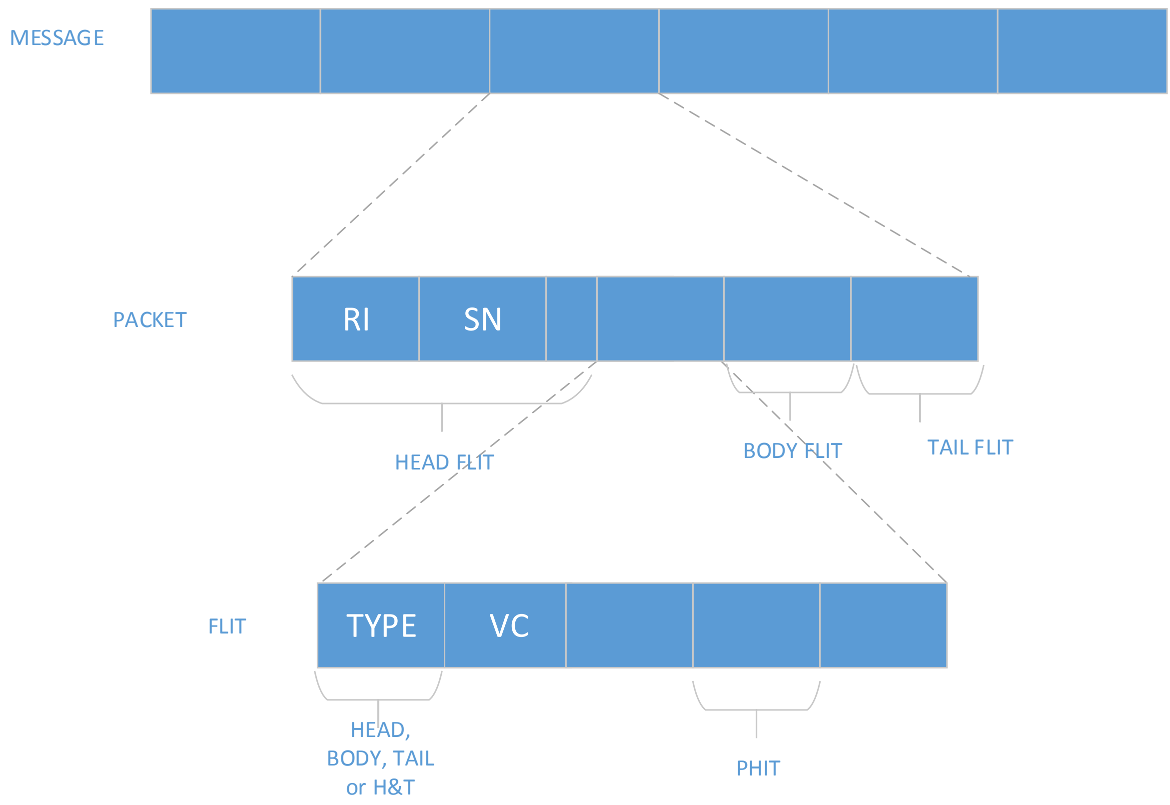


(Figure 2: Resources within one network node allocated by a flow control method)

- The control state tracks the resources allocated to the packet within the node and the state of the packet's traversal across the node
- To advance to the next node, the packet must be allocated bandwidth on an output channel of the node.
- As the packet arrives at a node, it is temporarily held in a buffer while awaiting channel bandwidth.

However, some flow control methods do not allocate buffers.

Interconnection Networks: Allocation Units



(Figure 3)

- At the top level, a message is a logically contiguous group of bits that are delivered from a source terminal to a destination terminal
- Because messages may be arbitrarily long, resources are not directly allocated to messages. Instead, messages are divided into one or more *packets* that have a restricted maximum length. By restricting the length of a packet, the size and time duration of resource allocation is also restricted, which is often important for the performance and functionality of the flow control mechanism.
- A packet is the basic unit of routing and sequencing. A packet consists of a segment of a message on which a packet header is prepended. The packet header includes routing information (RI) and, if needed, a sequence number (SN)
- A packet may be further divided into flow control digits or flits. A flit is the basic unit of bandwidth and storage allocation used by most flow control methods.
- Flits carry no routing and sequence information, and thus must follow the same path and remain in order. However, flits may contain a virtual channel identifier (VCID) to identify which packet the flit belongs to in systems where multiple packets may be in transit over a single physical channel at the same time.
- A flit is itself subdivided into one or more physical transfer digits or phits. A phit is the unit of information that is transferred across a channel in a single clock cycle. Although no resources are allocated in units of phits, a link level protocol must interpret the phits on the channel to find the boundaries between flits.

ALLOCATION UNIT	BIT LENGTH		
	MIN	TYPICAL	MAX
Phit	1	8	64
Flit	16	64	512
Packet	128	1K	512K

BUFFERLESS Flow Control

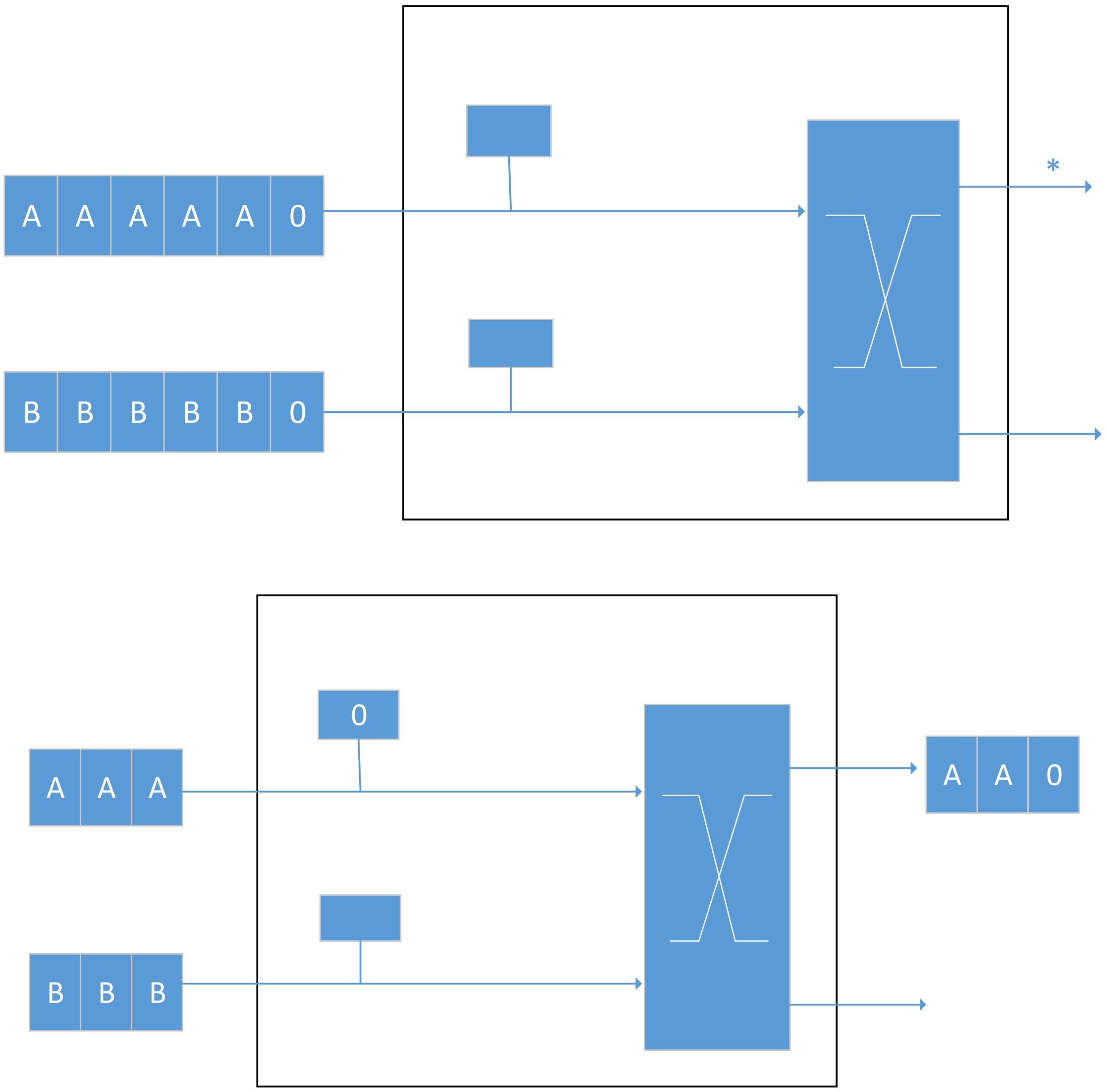


Figure 4:
a) Two packets A and B arrive at a network node. Both request output channel 0*
b) A acquires channel 0 and B is dropped. B must be retransmitted from the source