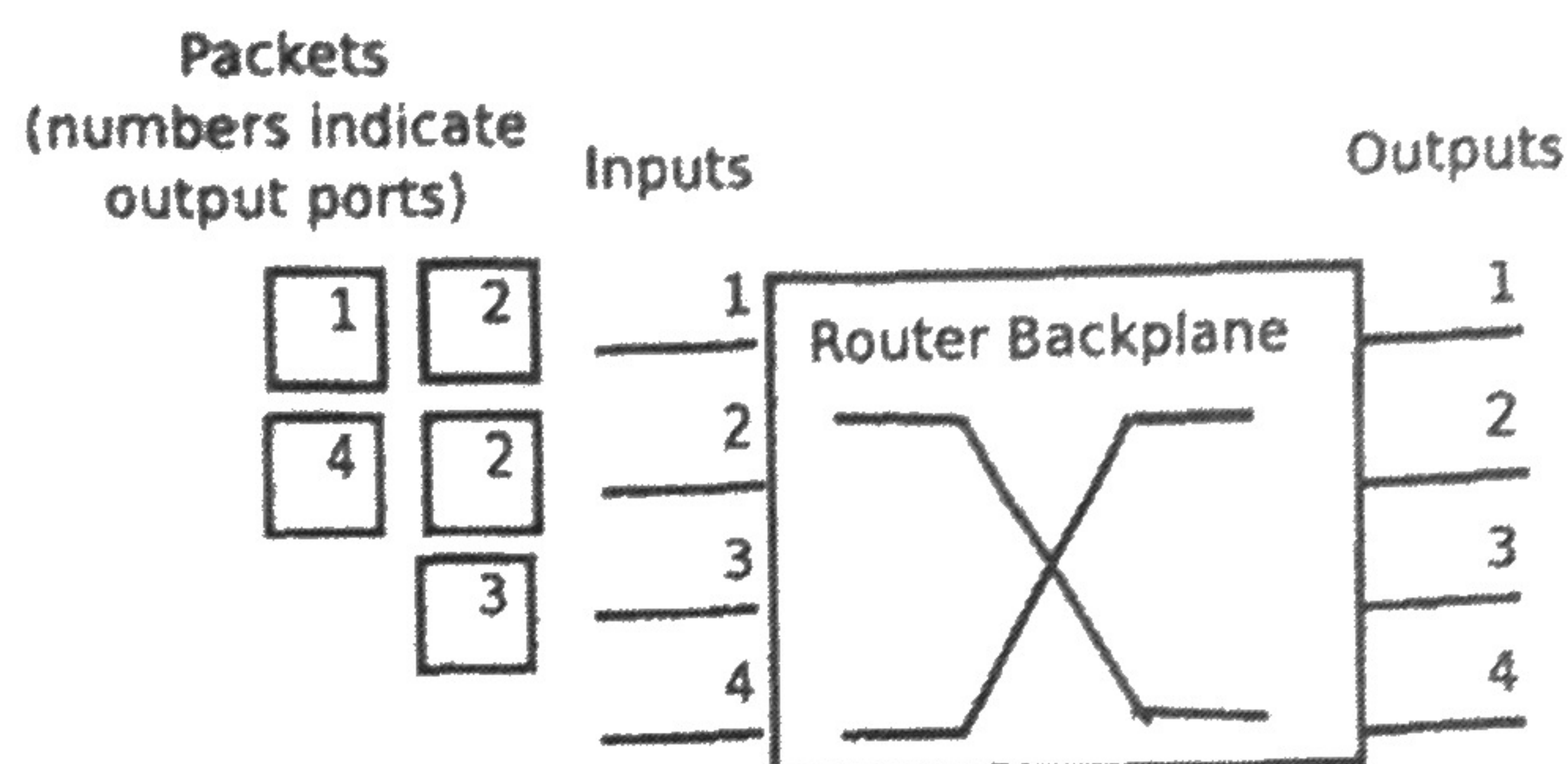


9. [8 points]: Consider the router backplane below, with packets arriving as shown. The number on each packet designates its intended output port. Suppose that each input and output port have a rate of 1 Gigabit per second.



- Suppose the router has a *bus backplane* with throughput of 5 Gigabits per second. What is the total maximum throughput that the router can achieve? Why?
- The example shows an example of *head-of-line blocking*. Explain why, and explain how virtual output queueing can fix the problem.
- Now suppose the router has a *crossbar switch backplane* with a throughput of 10 Gigabits per second (a "speedup" of 2) and virtual output queueing. Given the packet arrival pattern shown in the figure, give a sequence of matchings of input ports to output ports that results in 100% utilization (to save time, simple notation like "Round 1: $1 \rightarrow 2$ " is sufficient to indicate that you match input one to output two in round one). Your solution should have two rounds.

(Answer legibly in the space below.)

A. 4 Gbps. Only one input-output pair can use the bus at any time; only four inputs.

B. There are two packets for output 2 at the heads of queues. One of those results in either 1 or 4 being blocked, even though there could be a match to the output. (e.g., $1 \rightarrow 1, 2 \rightarrow 2, 3 \rightarrow 3$)

C. Round 1:
 $1 \rightarrow 1$
 $2 \rightarrow 2$
 $3 \rightarrow 3$

Round 2:
 $1 \rightarrow 2$
 $2 \rightarrow 4$

[many possible correct answers]

Name: