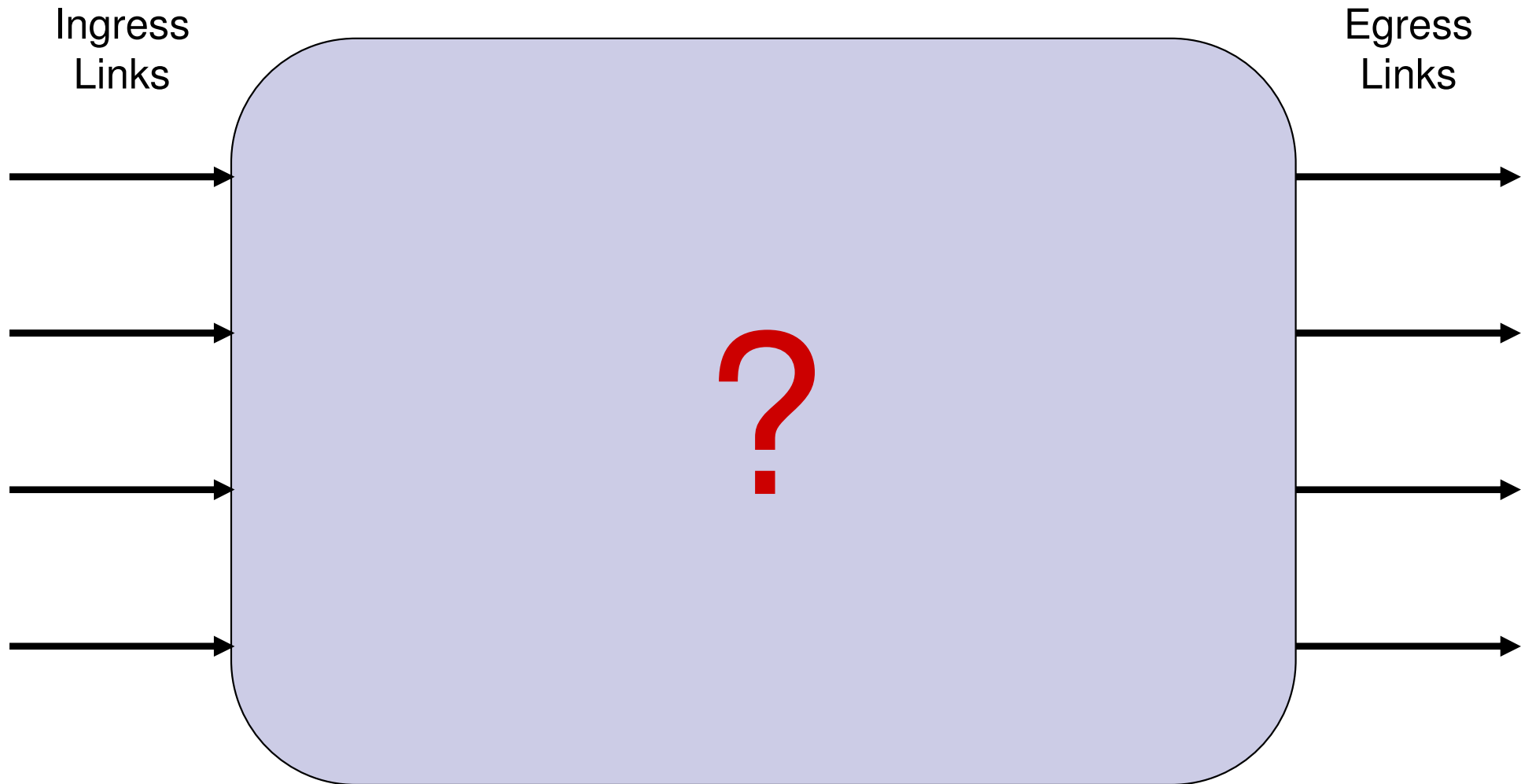




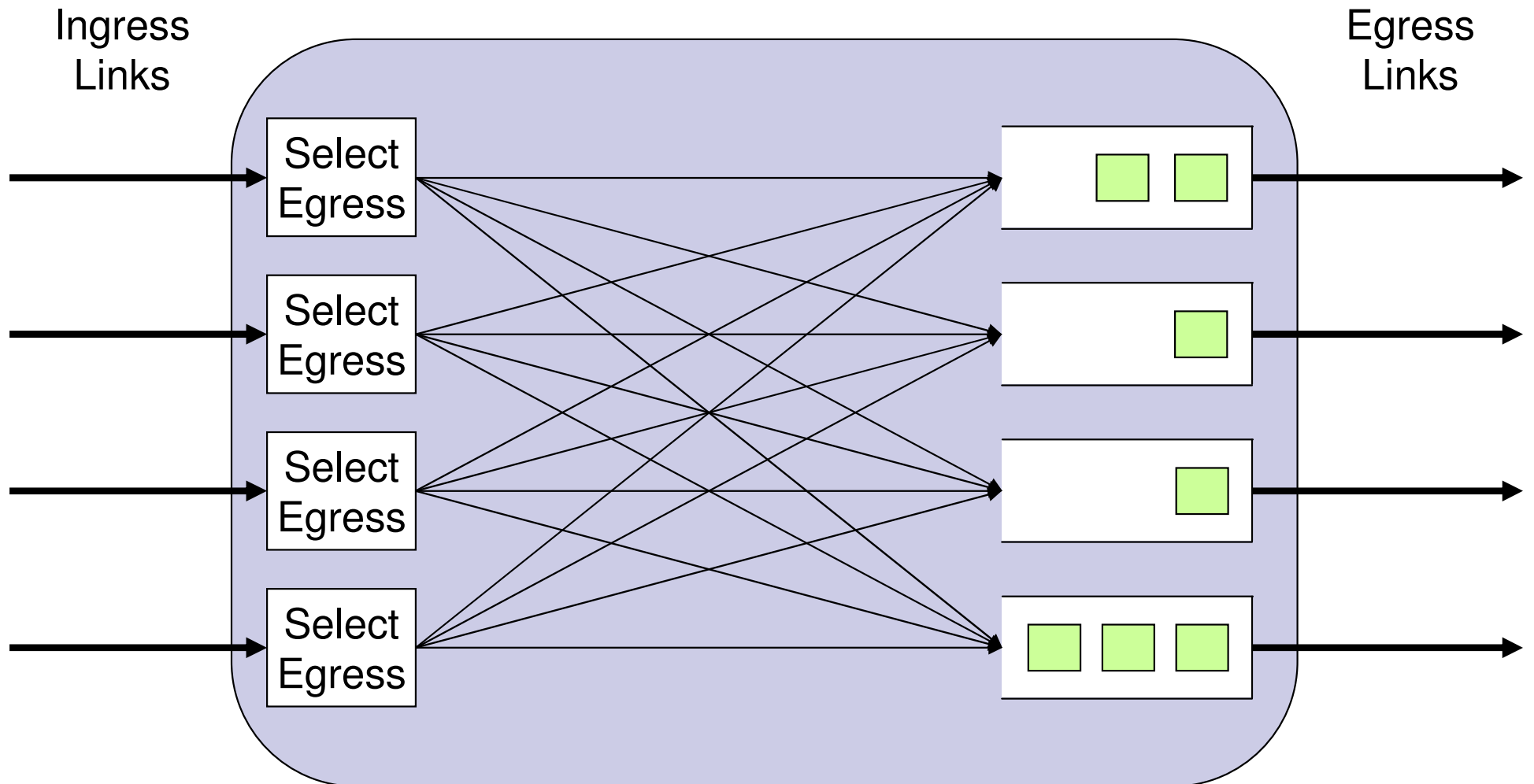
# Router Wrapup

Jeffrey Shafer

# What's inside a router?

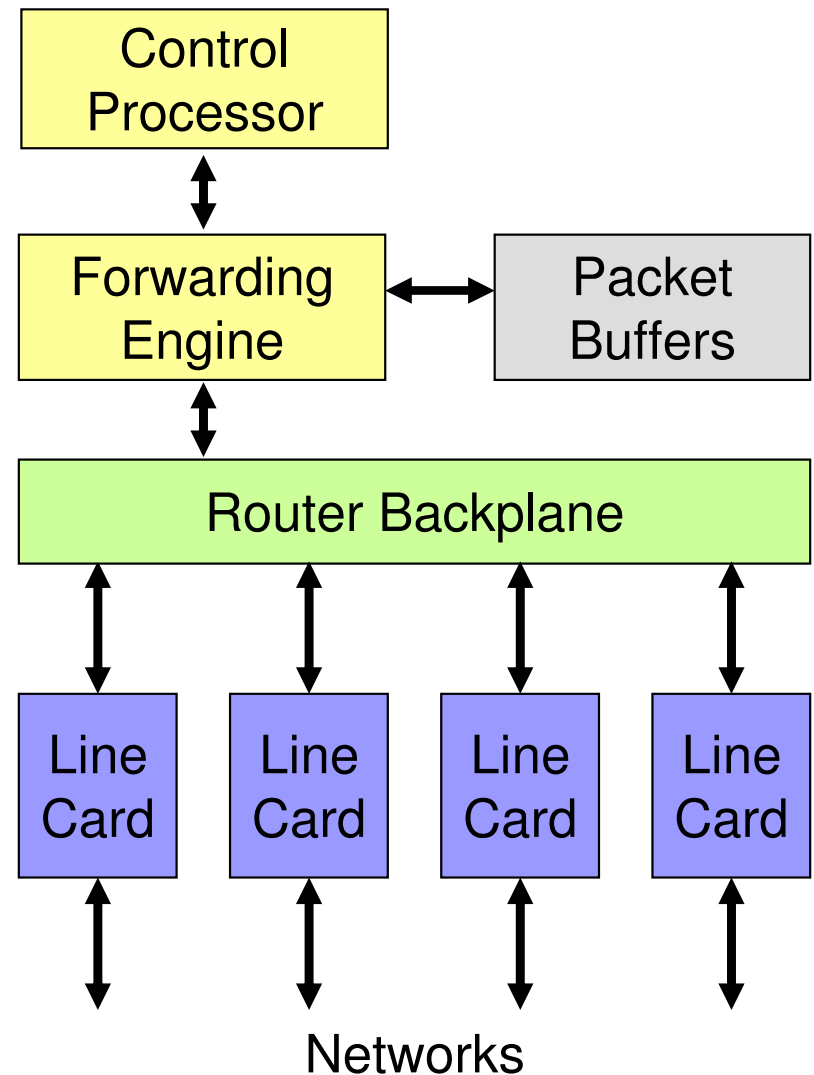


# Simplified model of a router



# Basic Router Components

- Key Modules
  - Network Interface
  - Packet processing
  - Packet buffering
  - Packet switching
- Processing and buffering can be centralized or decentralized





# Network Interface

## ■ PHY

- Transceiver for the physical medium
- Performs digital/analog conversion

## ■ MAC

- Transmits/receives data to/from the network
- Controls packet framing (e.g., Ethernet preamble, Ethernet CRC checksum, etc.)

# Packet processing

- Analyze packet and extract header information necessary for router functions
  - Might need to segment, forward, queue, police, reassemble, or discard packet
- Commonly divided into fast-path and slow-path sections for common and infrequent tasks
- Also includes administrative functions
  - Network management, configuring devices, diagnostics

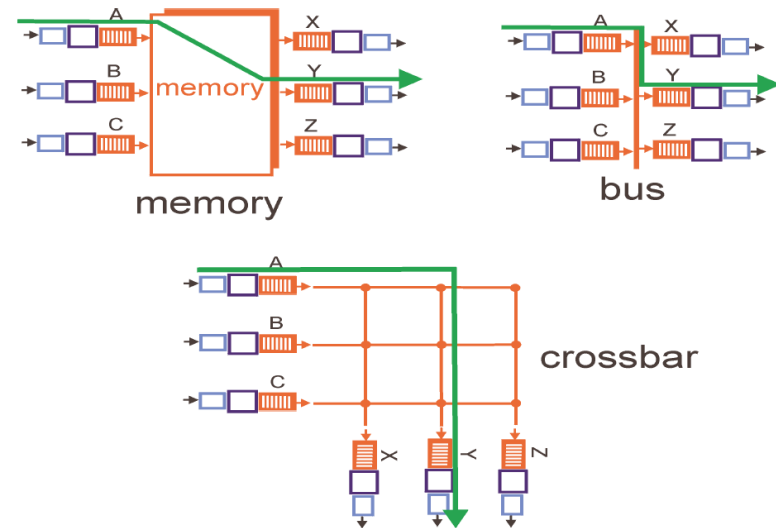


# Packet buffering

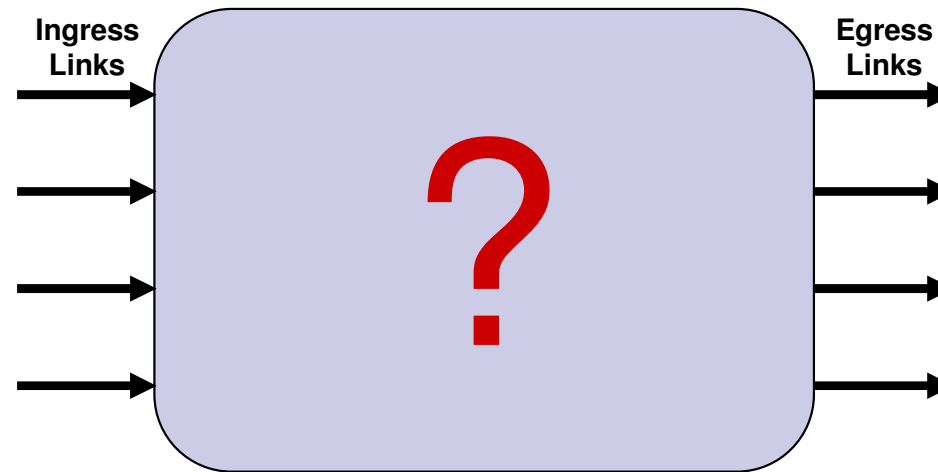
- Packets need to be buffered due to
  - Congestion on outbound ports
  - Delay due to higher-level protocols (e.g. ARP)
- Buffering can be centralized (shared memory) or distributed across router

# Packet switching

- Processing module determines where packet should go, while switch module carries out that task
- Three options for moving data from input port to output port
  - Shared Memory
  - Shared Bus
  - Crossbar



# Router Architecture



- No “best” design
- Many considerations
  - Cost, performance, power, functionality, etc.
- Routers follow common framework, but are unique in their implementation



# Packet Processing

- What does a router need to do?
- Driven by protocols
  - Ethernet
  - IP
  - ARP
  - ICMP
  - Transport: TCP, UDP, etc.

# On packet arrival...

## ■ Processing

- Buffer packet?
- Determine protocol (e.g., IP vs. ARP)
- Verify checksum, validate the packet, etc.
- Collect statistics?

## ■ What's next in the “common” (valid IP packet) case?

- Select egress link

# Selecting an Egress Link

- Forwarding table lookup
  - Longest prefix match
  - Determine next hop IP address and egress link
- What if no match?
- Is this sufficient to route the packet to an output queue?

Prefix	Next Hop	Port
63/8	128.34.12.1	3
128.42/16	128.34.12.1	3
156.3/16	128.36.21.1	2
156.3.224/19	128.36.129.1	1
128.42.96/20	128.37.37.1	4
128.42.128/24	128.36.129.1	1
128.42.160/24	128.36.21.1	2

# Updating the Destination Address

- ARP table lookup
  - Exact match on next hop IP address
  - Determine next hop MAC address
- What if no match?
- Is this sufficient to route the packet to an output queue?

IP	MAC
128.34.12.1	0C:FF:63:82:44:01
128.36.21.1	04:32:11:44:82:60
128.36.21.18	10:44:82:82:44:07
128.37.37.37	08:82:82:44:16:32
128.34.12.14	20:33:71:28:15:70
128.36.21.42	14:93:29:22:15:28

# Generating ARP Requests

- Broadcast on output port
  - Ask for MAC address of next hop IP address
- Wait for reply
  - What do you do with the packet?
  - How long should you wait?
- Receive reply
  - Update ARP table
  - Packet continues along forwarding path

# Receiving ARP Requests

- Does the IP address match the IP address of the interface that received the ARP request?
  - Another system is trying to determine your MAC address
  - Respond with the appropriate ARP reply on the same interface
- Should requests be forwarded if they aren't for the router?
- What if the IP address matches that of another interface in the router?

# Updating Packets

- Select egress link
- Update MAC address
- Forward packet to output queue?
  
- IP packet header must be modified
  - What needs to be modified?
  - When should it be modified?

# Buffering

- Why do packets need to be buffered?
  - Waiting for access to a resource (lookup table, switch, etc.)
  - Waiting for an ARP reply
  - ...
- What happens when buffers get full?
  - Packets have to be dropped
- How large do buffers need to be?
  - Statistical multiplexing



# Error Handling

- ICMP Messages

- Notify sender of errors

- Common error types

- Host/network unreachable

- No ARP response

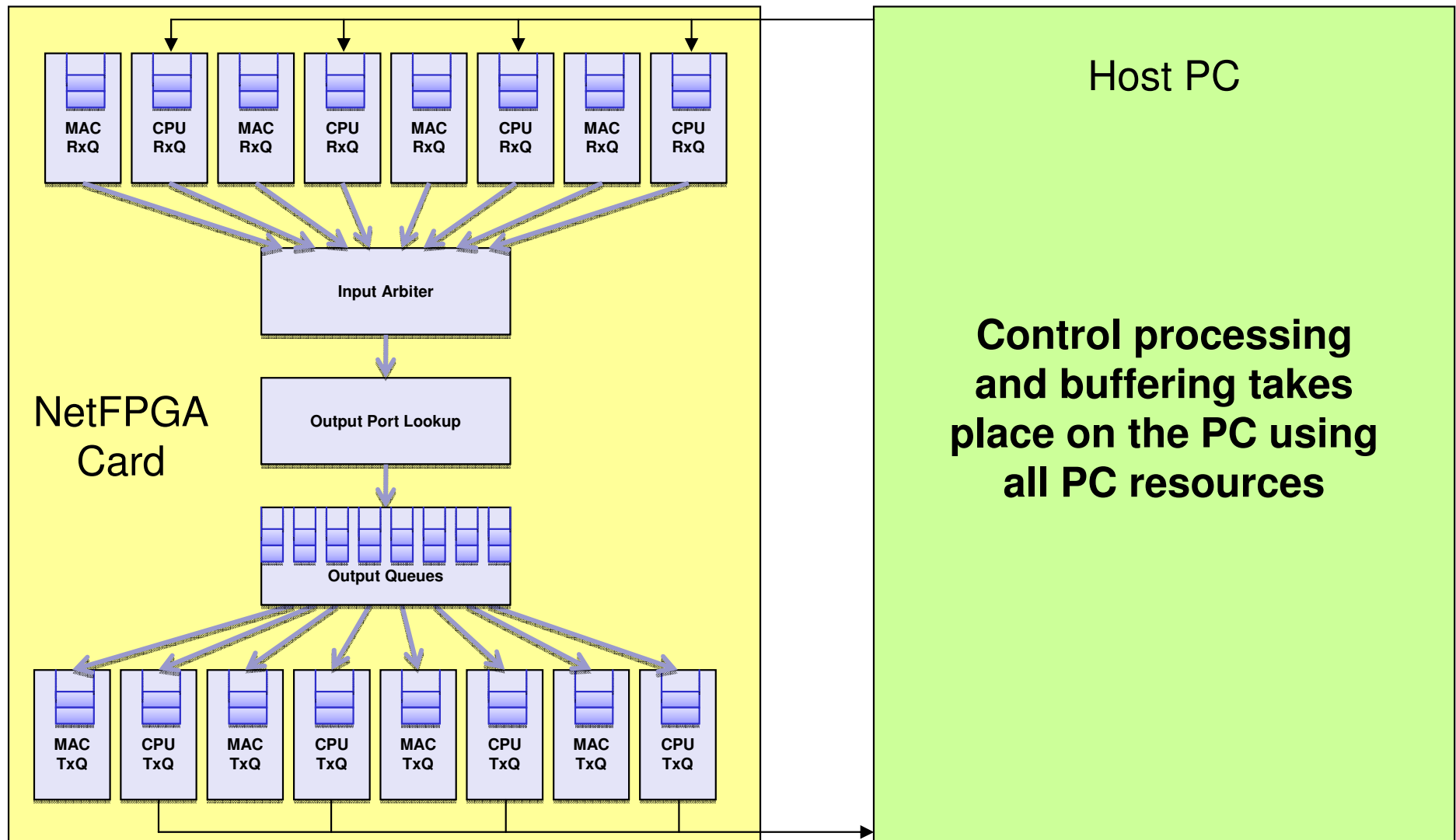
- Time exceeded

- TTL decremented to 0

- No route to host

- No entry in routing table

# NetFPGA Router Design





# Next Time

- Packet processing
  - Data plane vs. Control plane