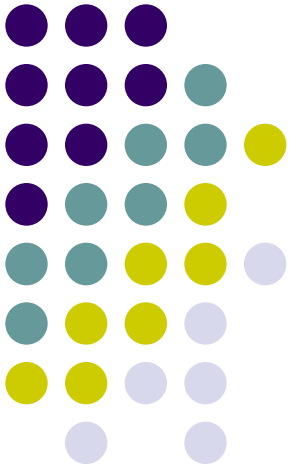
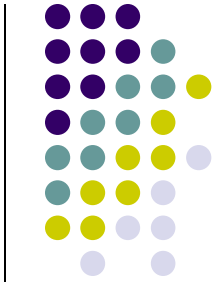
ELEN 4017

Network Fundamentals

Lecture 20



Purpose of lecture



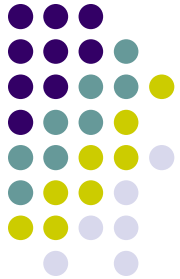
Chapter 3: Transport Layer

- TCP flow control
- Congestion control (briefly)

Chapter 4: Network Layer

- Introduction

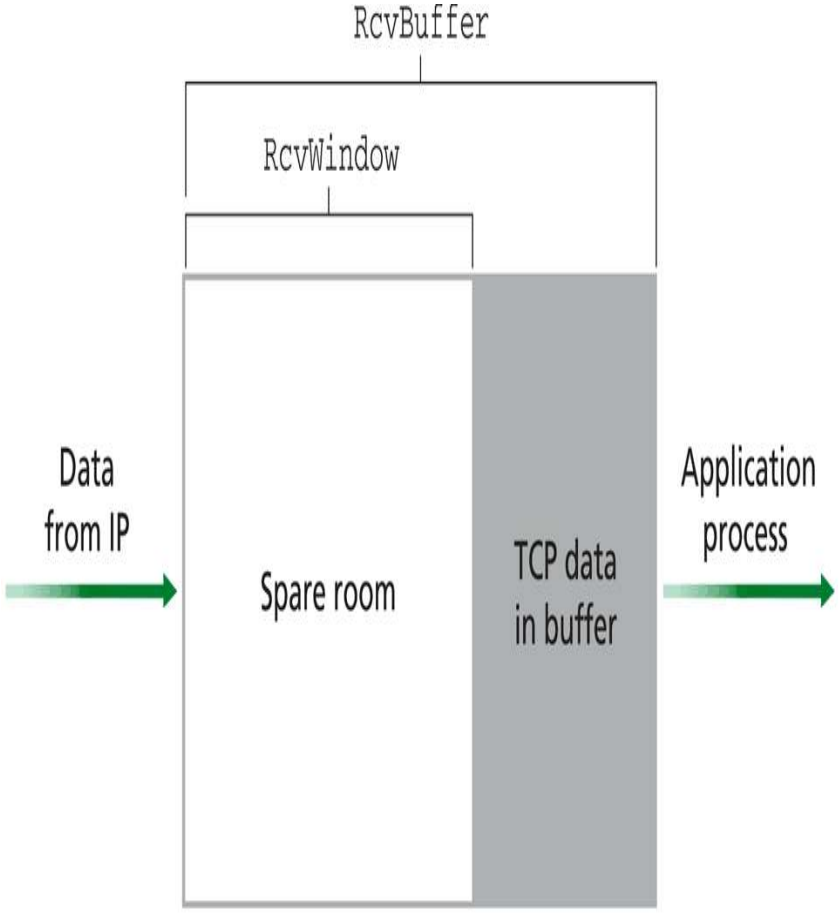
TCP flow control



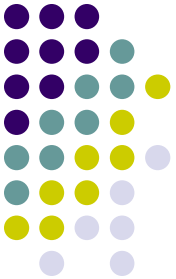
- With TCP data that is correctly received, is then stored in a buffer → not immediately delivered to the application.
- Its possible that the application may be busy with some other task and only reads the data periodically.
- Thus its possible that the **receiver buffer can overflow**, if data is sent too quickly.
- Flow control is thus a **speed matching service**.
- Lets consider a simplified version of TCP flow control. **Assume that out-of-order packets are discarded.**

Receive window

- Consider sender is host A and receiver is host B.
- **Sender** maintains a variable called **receive window**.
- It is used to give the sender an idea of much free buffer space is available at the **receiver**.
- The application process on receiver periodically reads data from buffer.
- **RcvBuffer** is the size of buffer on receiver.
- **RcvWindow** is the spare room available at any point in time.

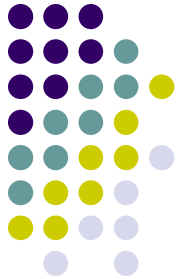


Receive Window



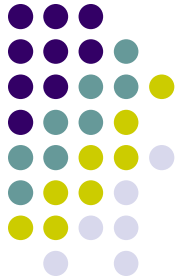
- **`LastByteRead`**: number of the last byte read by application on Host B
- **`LastByteRcvd`**: number of last byte that has arrived from network
- **`LastByteRcvd - LastByteRead ≤ RcvBuffer`**
- **`RcvWindow = RcvBuffer - [LastByteRcvd - LastByteRead]`**
- **Host B tells host A how much spare room it has** in its connection buffer by placing its **current value of RcvWindow** in every segment it sends to A.
- What is **initial value of RcvWindow?**

Sender side flow control

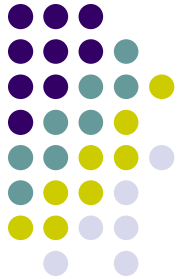


- Host A keeps track of 2 variables:
- **`LastByteSent`** and **`LastByteAcked`**
- The difference between these two variables is the amount of unacknowledged data
- Host A prevents buffer overflow by ensuring that:
- **`LastByteSent - LastByteAcked ≤ RcvWindow`**

A little problem

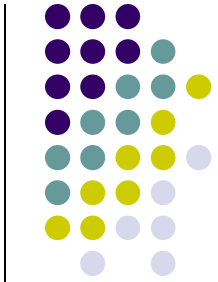


- Can you think of a possible flaw in the scheme ?
- Consider host B has **`RcvWindow`**=0 and it has nothing to send to A.
- If application empties the buffer, the receive window increases, but host A is never notified.
- Thus TCP mandates that Host A will continue to send segments with one data byte when B's receive window is zero.
- These segments will be acknowledged by the receiver and when buffer is emptied, host A will be informed of a non-zero receive window size.



- Flow control applet

Purpose of lecture



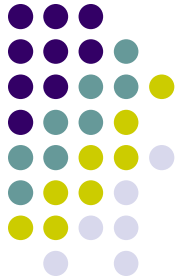
Chapter 3: Transport Layer

- TCP flow control
- Congestion control (briefly)

Chapter 4: Network Layer

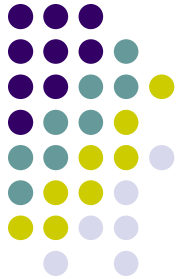
- Introduction

Overview of congestion control



- Network congestion is caused when too many sources attempting to send data at too high a rate.
- To treat congestion mechanisms are needed to throttle the sender.
- Approaches to congestion control:
  - **End-to-end congestion control**: Network layer provides no explicit support to transport layer for congestion control.
  - **Network-Assisted congestion control**: Network layer components (routers) provide explicit feedback to the sender.

End-to-End congestion control



- TCP must follow this approach since IP provides no feedback to end systems.
- TCP segment loss (indicated by timeout or triple duplicate ACK) is taken as an indication of network congestion.
- TCP responds by decreasing window size.
- More recent proposals suggest to use RTT values to indicate congestion.

Network-assisted Congestion control

- Used in IBM/SNA, DEC, ATM
- Information is fed back to the sender in two ways:
  - Direct feedback → a **choke** packet is sent from router to sender to indicate congestion.
  - Update of field in packet to indicate congestion. Upon receipt of a marked packet, receiver notifies sender.

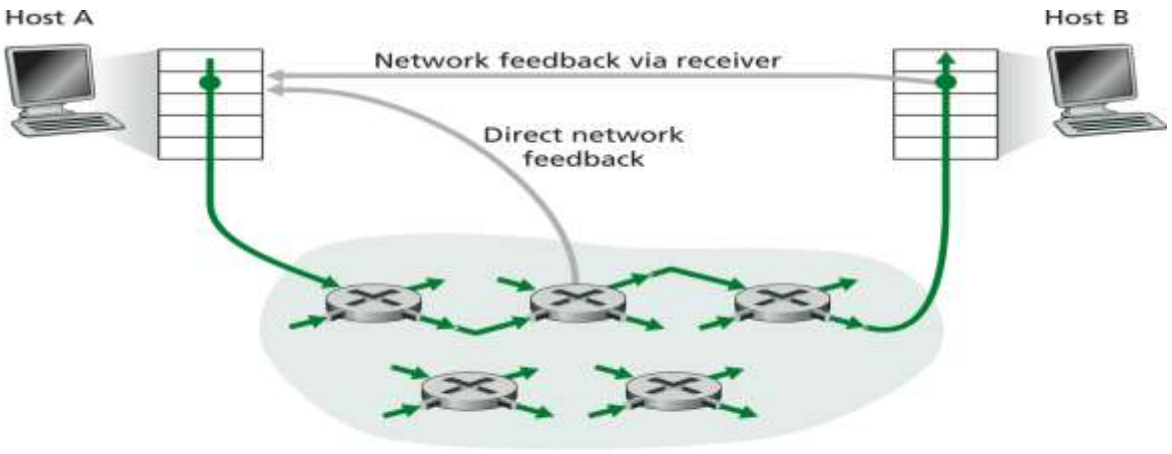
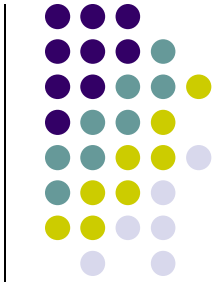


Figure 3.48 ♦ Two feedback pathways for network-indicated congestion information

Purpose of lecture



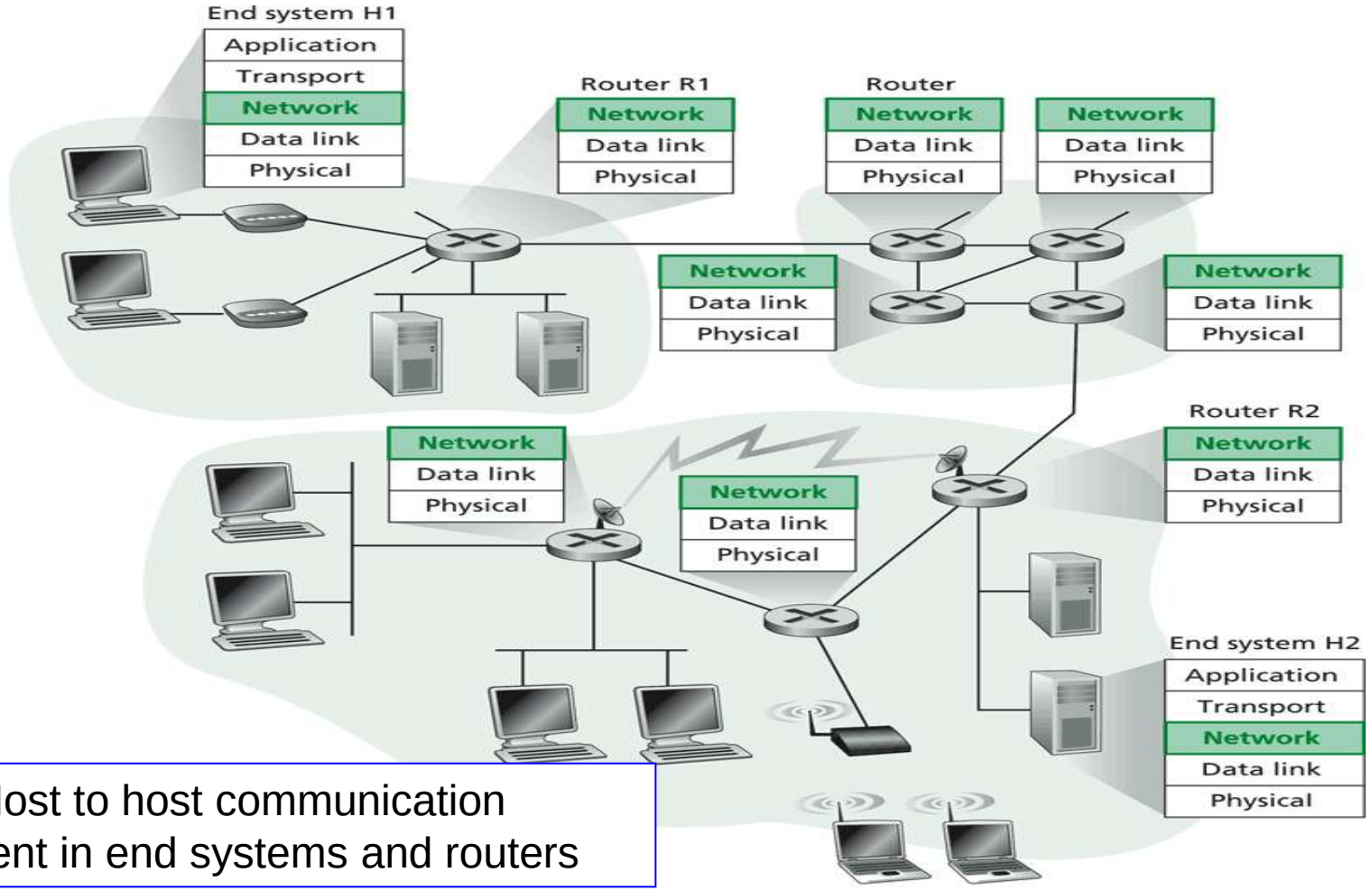
Chapter 3: Transport Layer

- TCP flow control
- Congestion control (briefly)

Chapter 4: Network Layer

- Introduction

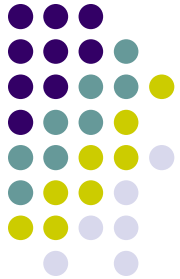
Network layer



- Host to host communication
- Present in end systems and routers

Figure 4.1 ◆ The network layer

Terminology



- **Router** – Network layer device which is responsible to forward datagrams from input link to output link.
- **Forwarding** – Transfer of a packet from the input link to the output link within a **single** router.
- **Routing** – involves all network routers, whose **collective interaction via routing protocols** determines the paths that packets take.

Forwarding tables

- Each router contains a **forwarding table** which indicates how to forward the packet through the router.
- **How are routing tables configured ?**
- **Routing algorithms** determine what values are inserted into forwarding tables.

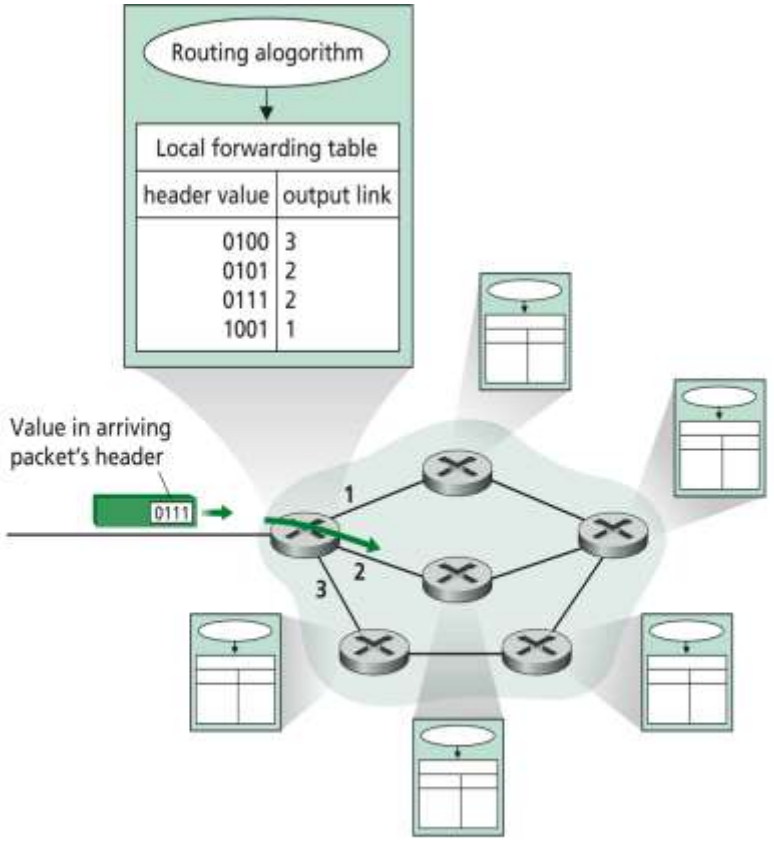
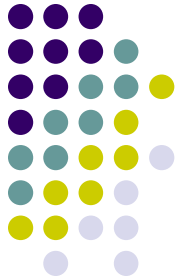
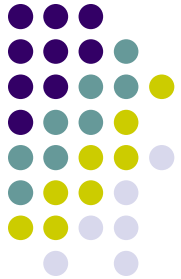


Figure 4.2 ♦ Routing algorithms determine values in forwarding tables

Services provided by network layer



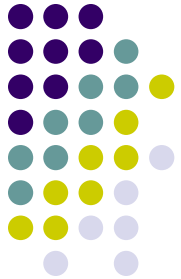
- Guaranteed delivery
- Guaranteed delivery with bounded delay
- In-order packet delivery
- Guaranteed minimal bandwidth (emulating a point-to-point transmission link)
- Guaranteed maximum jitter – jitter is the amount of time between the transmission of two successive packets.
- Security services – encryption
- Which of the above does IP provide ?



Network Architecture	Service Model	Bandwidth Guarantee	No-Loss Guarantee	Ordering	Timing	Congestion Indication
Internet	Best Effort	None	None	Any order possible	Not maintained	None
ATM	CBR	Guaranteed constant rate	Yes	In order	Maintained	Congestion will not occur
ATM	ABR	Guaranteed minimum	None	In order	Not maintained	Congestion indication provided

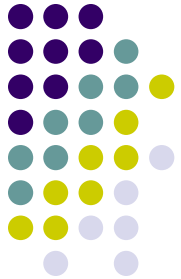
Table 4.1 ♦ Internet, ATM CBR, and ATM ABR service models

Asynchronous Transfer Mode (ATM)



- ATM architecture provides for multiple service models → being able to provide different classes of service over the same network.
- **Constant Bit Rate service (CBR)**
  - 1st ATM service driven by interest from telco.
  - Aim to provide same service as fixed bandwidth dedicated line (Circuit switch)
  - ATM cells (packets) provide guaranteed limits for end-to-end delay, jitter, fraction of cells lost, …
- **Available Bit Rate service (ABR)**
  - Improvement over Internet Best effort.
  - Cells are not re-ordered. Cell transmission rate is guaranteed.

ATM

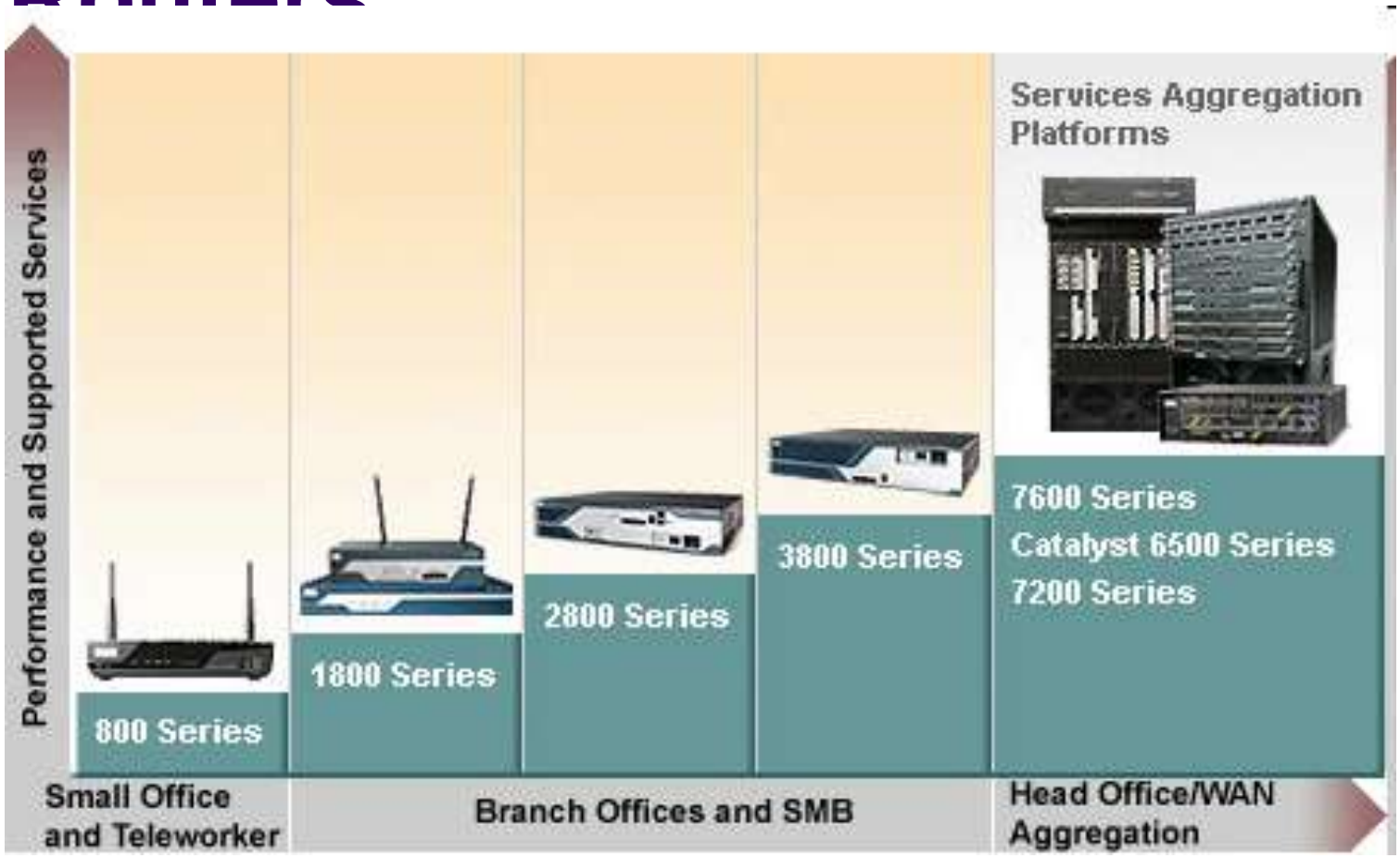


- ATM is connection-oriented at the network layer – thus is called a virtual circuit network.
- In contrast IP does not provide this – it is termed a datagram network.
- ATM provides network-assisted congestion indicators.
- ATM is mainly used for high-speed transmission links, and can carry IP by using adaptation layer.

Datagram networks

- Lets consider a generic datagram network before looking specifically at Internet and IP.
- In datagram network each time an end system wants to send a packet, it stamps the packet with the address of the destination end system and pops the packet into the network.
- There are no connections established, as compared to a VC network.
- As a packet is transmitted from source to destination, it passes through a series of routers. Each of the routers use the **destination address** to look up the appropriate output link.

Routers



- http://www.progent.com/images/cisco-routers-1.gif