Computer Networks and QoS

- QoS
- ATM
- QoS implementations
- Integrated Services
- Differentiated Services

Quality of Service (QoS)

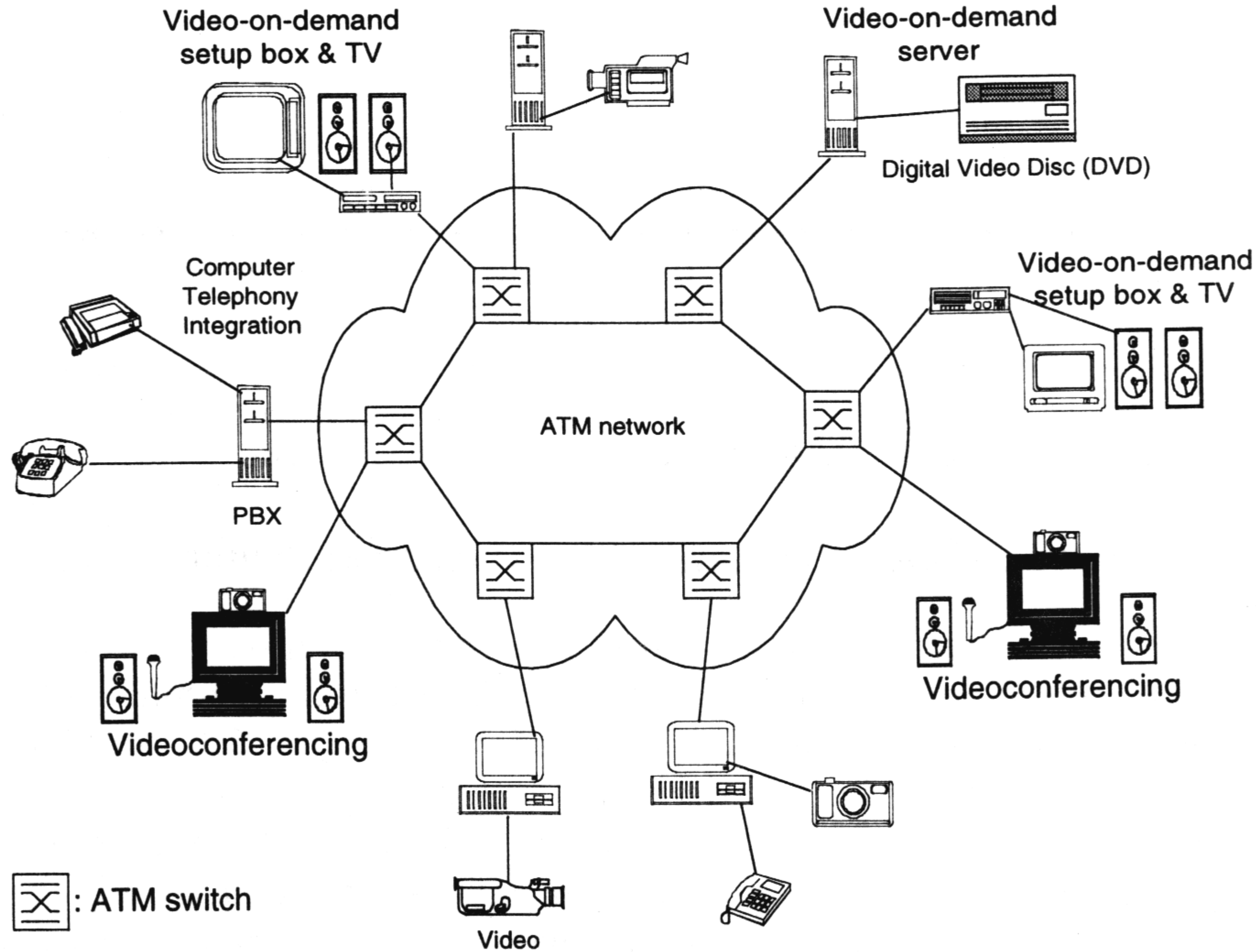
- The data transfer requirements are defined with different QoS parameters
  - + e.g., delay, jitter, error rate, capacity
- The customer negotiates the QoS parameters with the service provider before the use of service
- The highest protocol level is used in negotiations
- Parameters are transformed and distributed to the lower levels

QoS Parameters

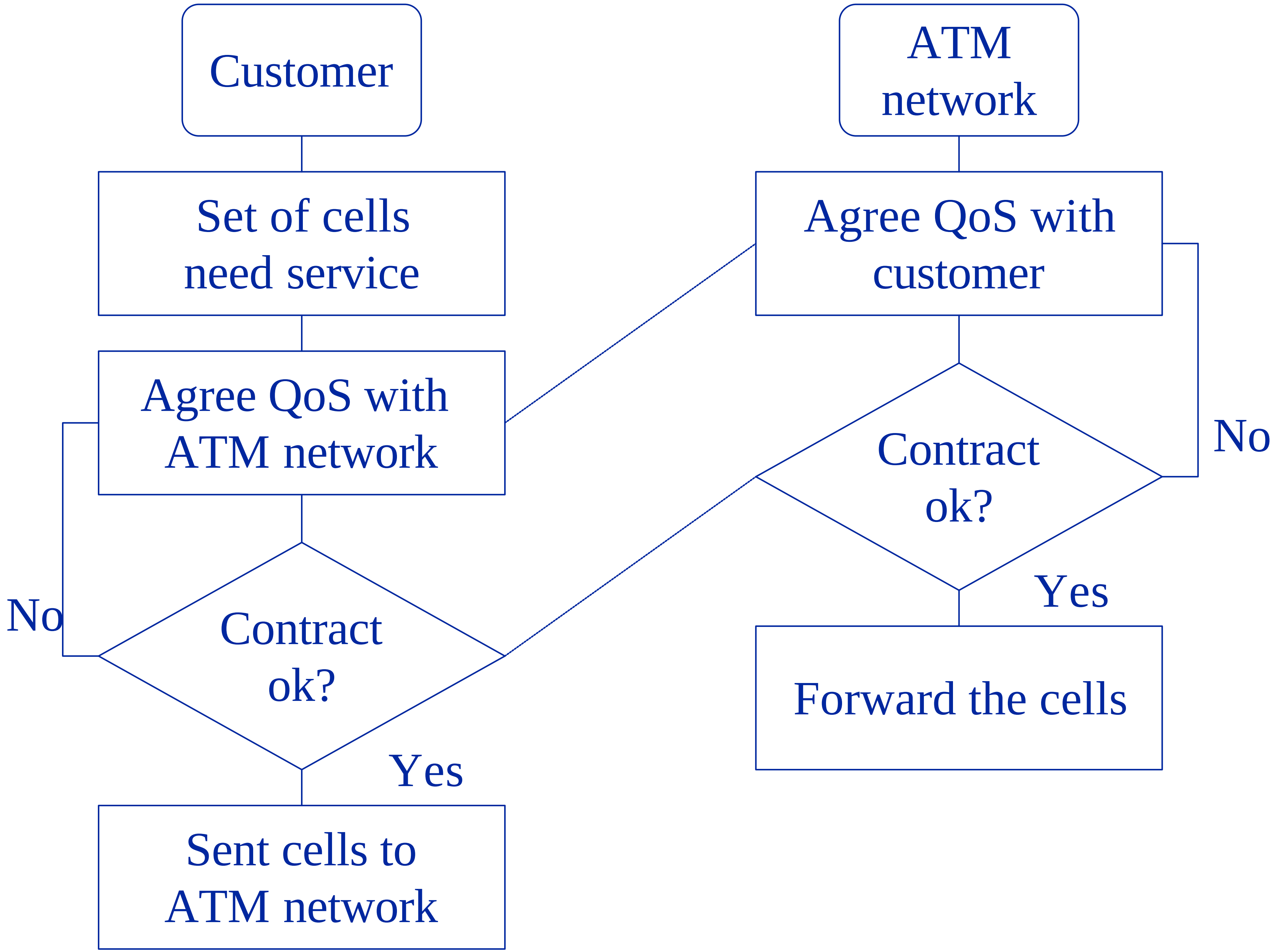
- Bandwidth
- Delay
- Jitter
- Error rate
- Best effort / guaranteed

ATM

- Can be used both voice, data, and multimedia transfer
- ATM uses 53 byte cells
- The switching of cells is fast (ASIC circuits)
- Optical fiber: 155 Mbps, 622 Mbps, 2.5 Gbps
- Twisted pair: 25 Mbps
- QoS parameters have to be agreed before hand



Video-on-demand
setup box & TV
Video-on-demand
server
Digital Video Disc (DVD)
Computer
Telephony
Integration
Video-on-demand
setup box & TV
ATM network
PBX
Videoconferencing
Videoconferencing
Video
: ATM switch


Customer
ATM network
Set of cells need service
Agree QoS with customer
Agree QoS with ATM network
Contract ok?
No
Yes
Contract ok?
No
Yes
Forward the cells
Sent cells to ATM network

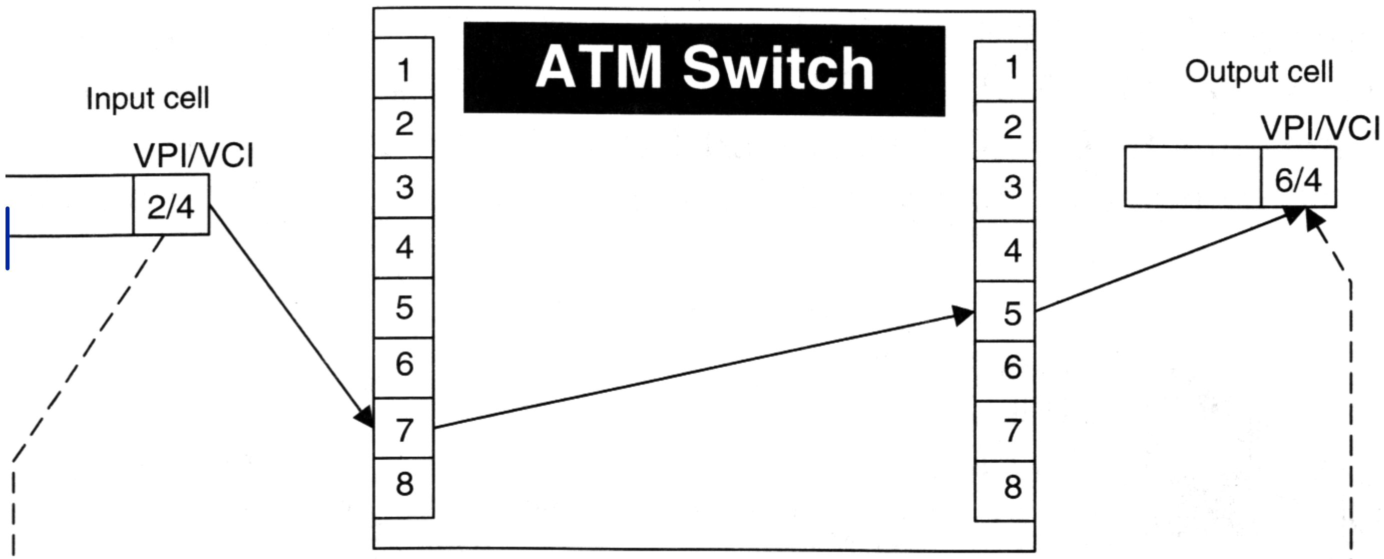
Cell Switching

- ATM network builds connections, which go through the ATM switches
  + Virtual Circuit Connection (VCC)
- Two ATM switches have a Virtual Connection (VC)
- Connections can be either permanent (PVC) or switched (SVC)

Cell Switching (cont.)

- Several connections can share a path
  + Virtual Path (VP)
- Virtual paths have a identification pair
  + VP Identifier / VC Identifier (VPI/VCI)

ATM Switch



Routing table for input port 7	
VPI/VCI	Output port
1/3	2, 5, 6
3/2	5
2/4	5
2/9	5

VPI/VCI translation table for output port 5	
VPI/VCI for this SW	**VPI/VCI for next SW**
1/3	5/2
3/2	4/1
2/4	6/4
2/9	6/9

Signaling

- Connection setup requires signaling
- First the QoS requirements are checked and then the success of connection
- Private network:
  - + User Network Interface (UNI)
  - + Private-Network Node Interface (P-NNI)

Adaptation Layers

- AAL1: audio and video
- AAL2: variable bit rate
- AAL3: connection data
- AAL4: connectionless data
- AAL5: LAN emulation

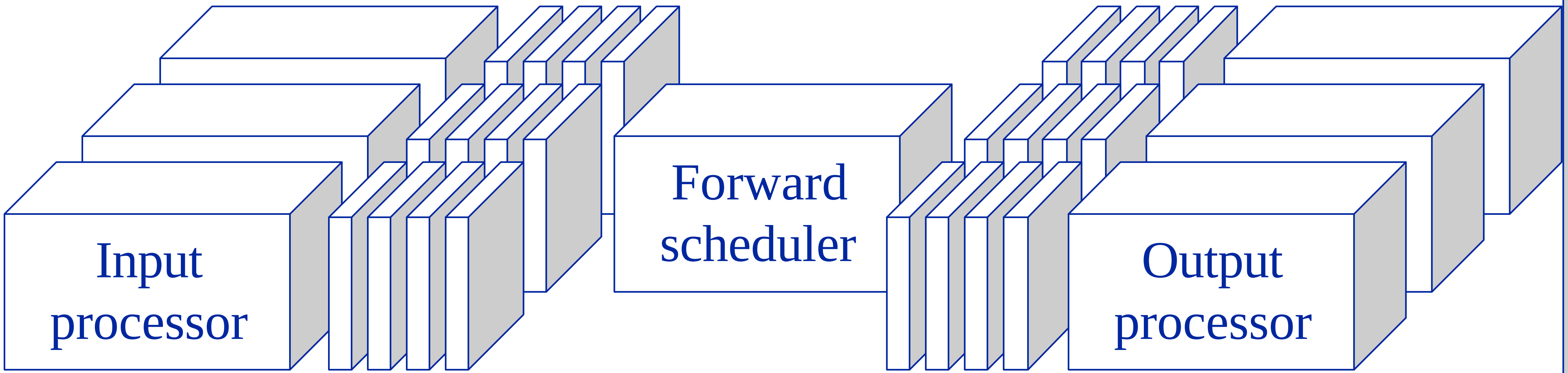
ATM Adaptation Layers

	AAL1	AAL2	AAL3	AAL4	AAL5
Timing	Isochronous		Bursty		Both
Data Rate	Constant	Variable			Both
Connection	Connection-oriented			Connectionless	Both
Applications	Voice & circuit emulation	Compressed video and audio	Data	Data	All

QoS Implementations

- The task of the router is to forward the incoming packets to correct output port
  + the responsible unit is scheduler
  + scheduler can be implemented as software or hardware
  + individual packets have to wait their turn in buffer
- Also in ATM switch scheduler controls individual cells

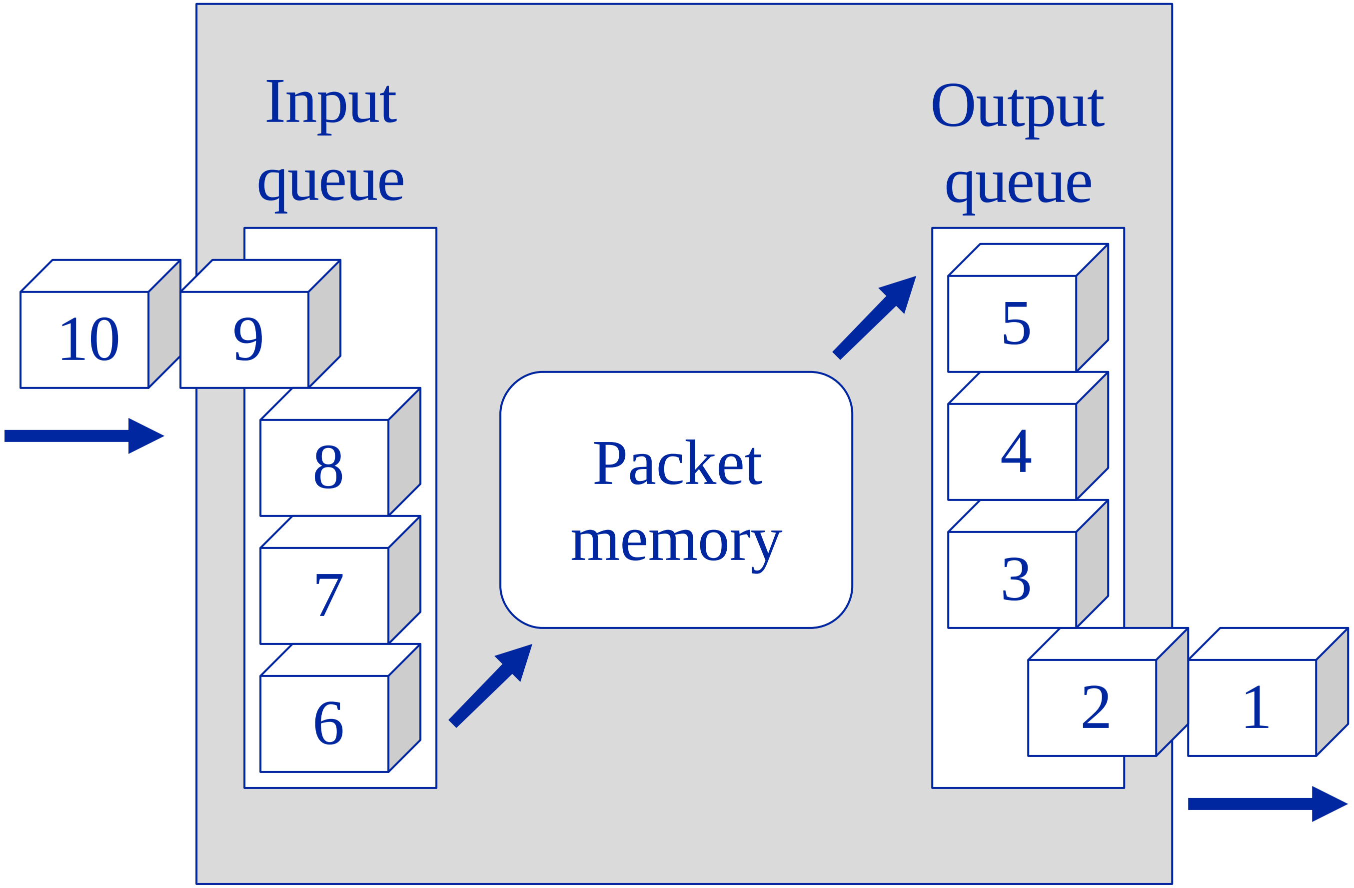
Router Operation



Queuing

- If the queue is full, the packet has to be discarded
  + Buffers should not get full
- Most simple queue is so called FIFO queue
  + the first arrived packet is forwarded to right output queue (first-in-first-out)

FIFO Queue



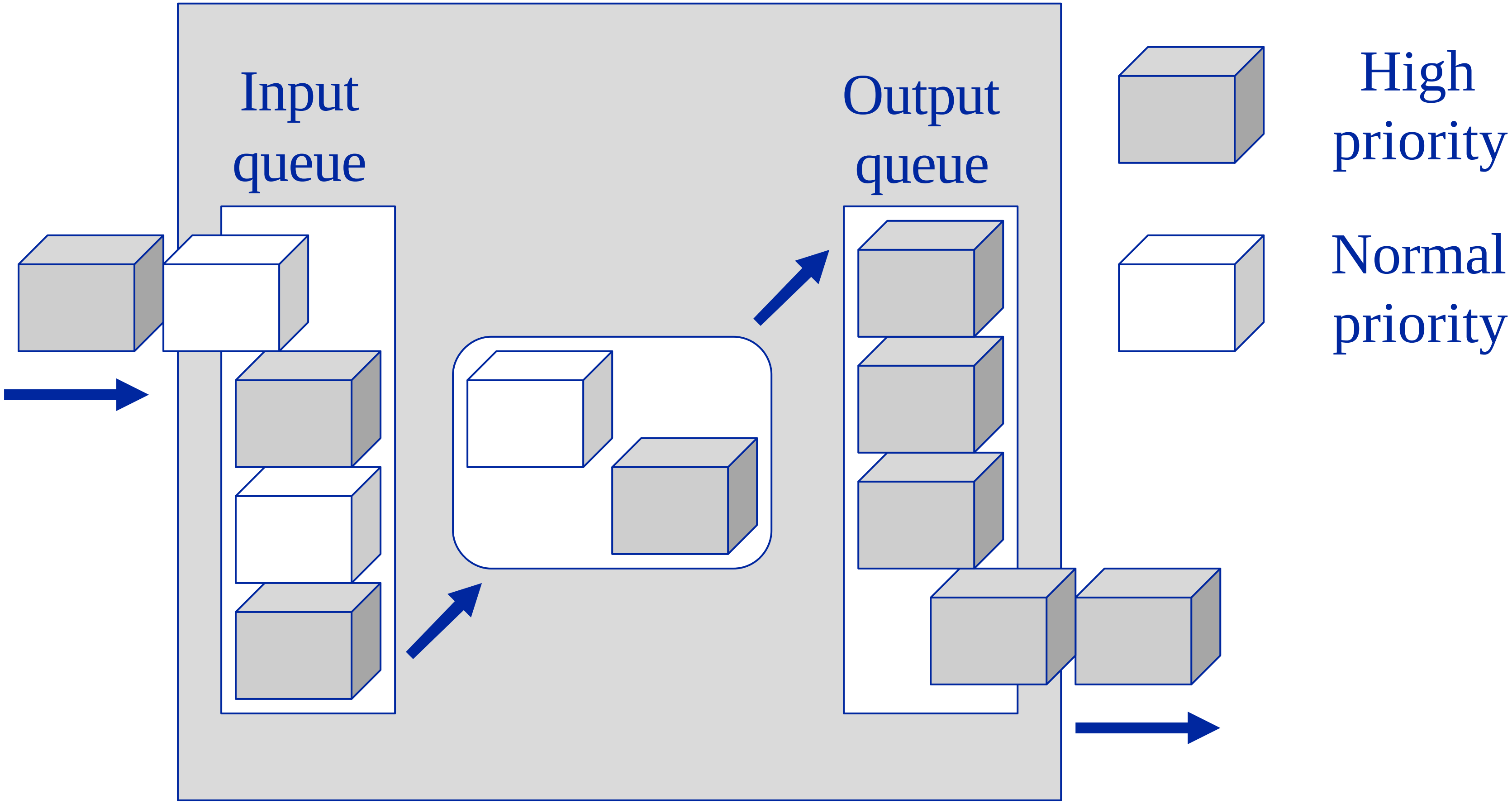
Pros and Cons

- FIFO queue filters well bursts, when the load level is low
- When the load level is high, FIFO causes delay for all packets
  - + high priority traffic suffers
  - + if queue gets full, all further incoming packets are discarded

Priorities

- The simple solution is to prioritize the traffic
  - + e.g., real-time traffic has higher priority
- Packet classification causes extra work load

Priority Queue



Pros and Cons

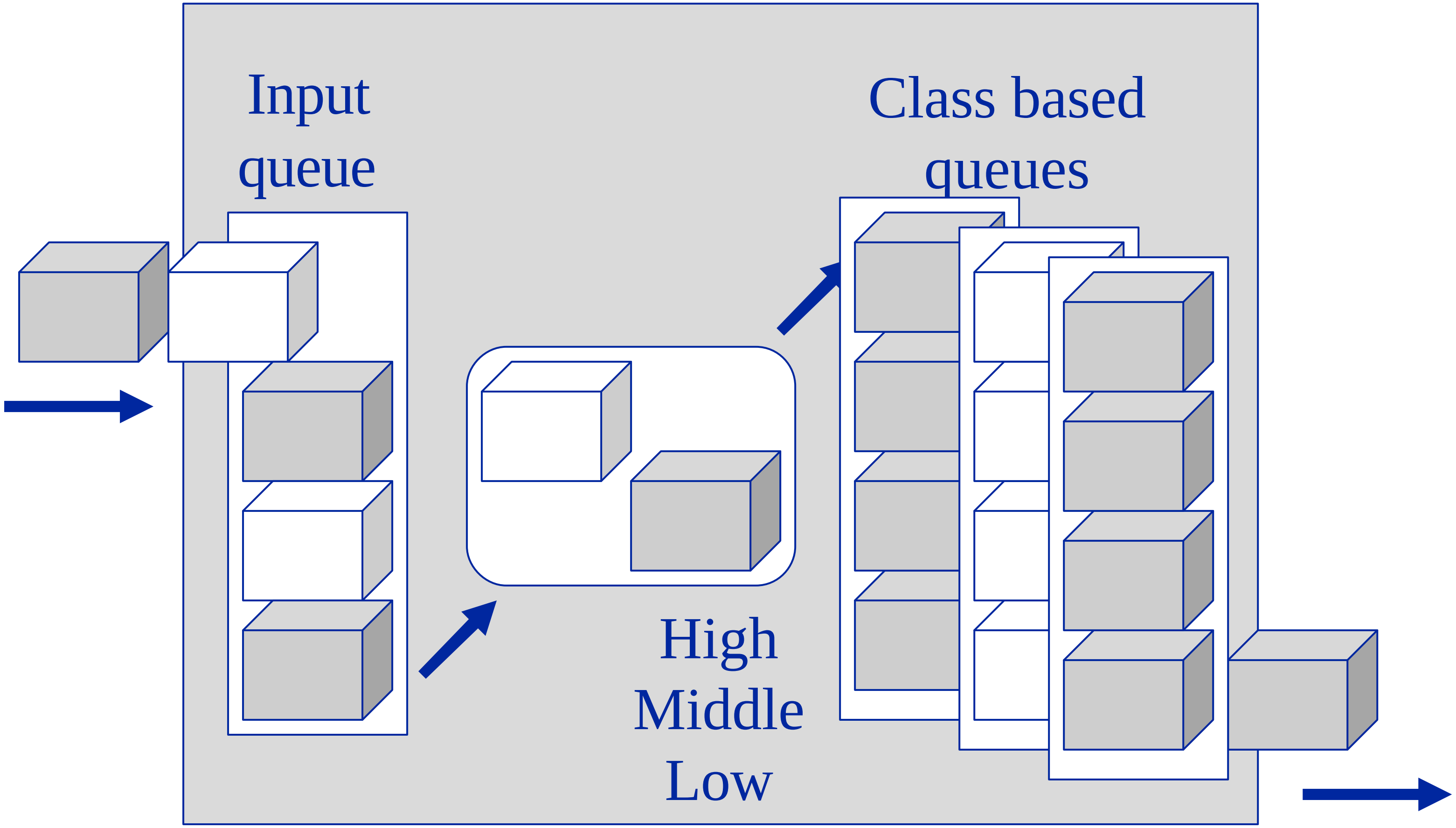
- Scheduler implementation is simple

- Classification is difficult
- High priority traffic can block the router
  + low priority traffic stalls

Service Classes

- Different services can have their own output queues
  - + high priority traffic does not stall low priority traffic
- Several output queues are required

Class Based Queue



Pros and Cons

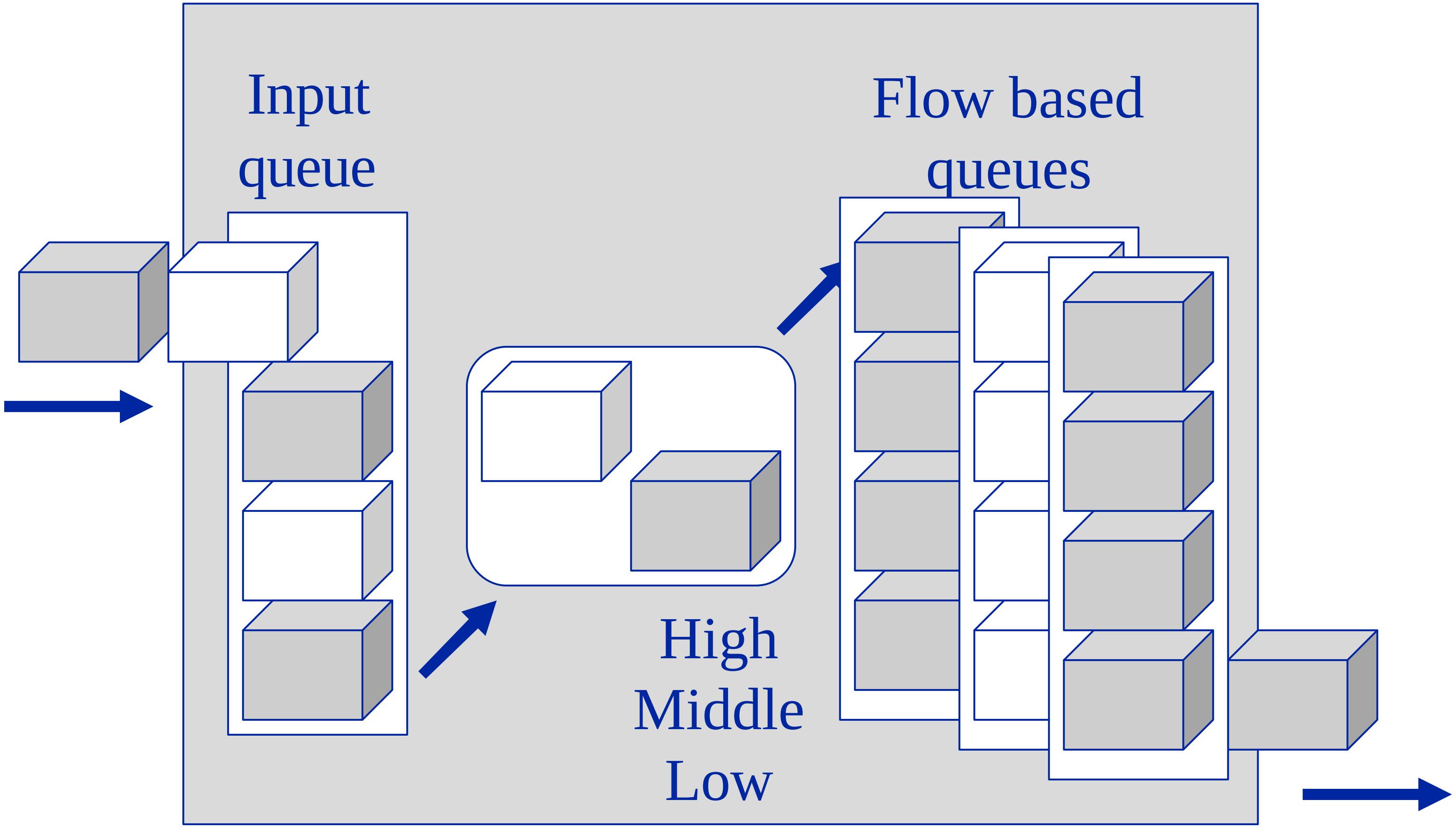
- Simple way to classify traffic

- Does not scale well
  + scheduling is complicated
  + queue control slows down the fast traffic

Weighted Queues

- Weighted Fair Queuing (WFQ)
- Capacity is divided according to the amount of traffic
  - + low capacity traffic gets the higher priority
  - + high capacity traffic shares the rest of resources
- Traffic can be divided into flows
  - + Each flow is assigned into a buffer according to the amount of traffic

Weighted Fair Queuing



Pros and Cons

- Fairness
  - \+ one flow does not block all other traffic
- Scalability
  - \+ computation creates extra load
- Classification
  - \+ how different flows are assigned to groups

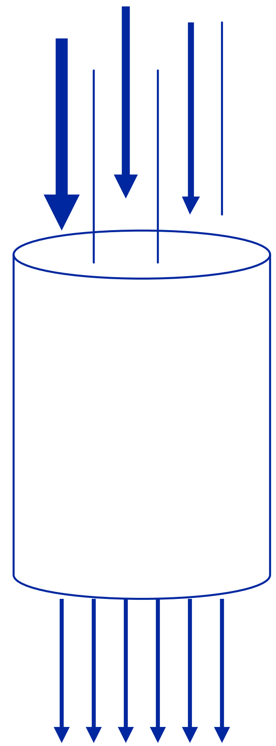
Traffic Shaping

- Individual traffic flows are shaped more suitable
  - + packet put to wait in queues
  - + packets are discarded
- It is also possible to shape incoming traffic
  - + Not necessarily a competing method, but rather supporting with queuing

Burst Filtering

- Most simple method to shape traffic is to filter bursts
- So called leaky bucket algorithm can be used
  + too large traffic bursts are filtered
  + if necessary, packets are discarded
- Was used originally in ATM networks

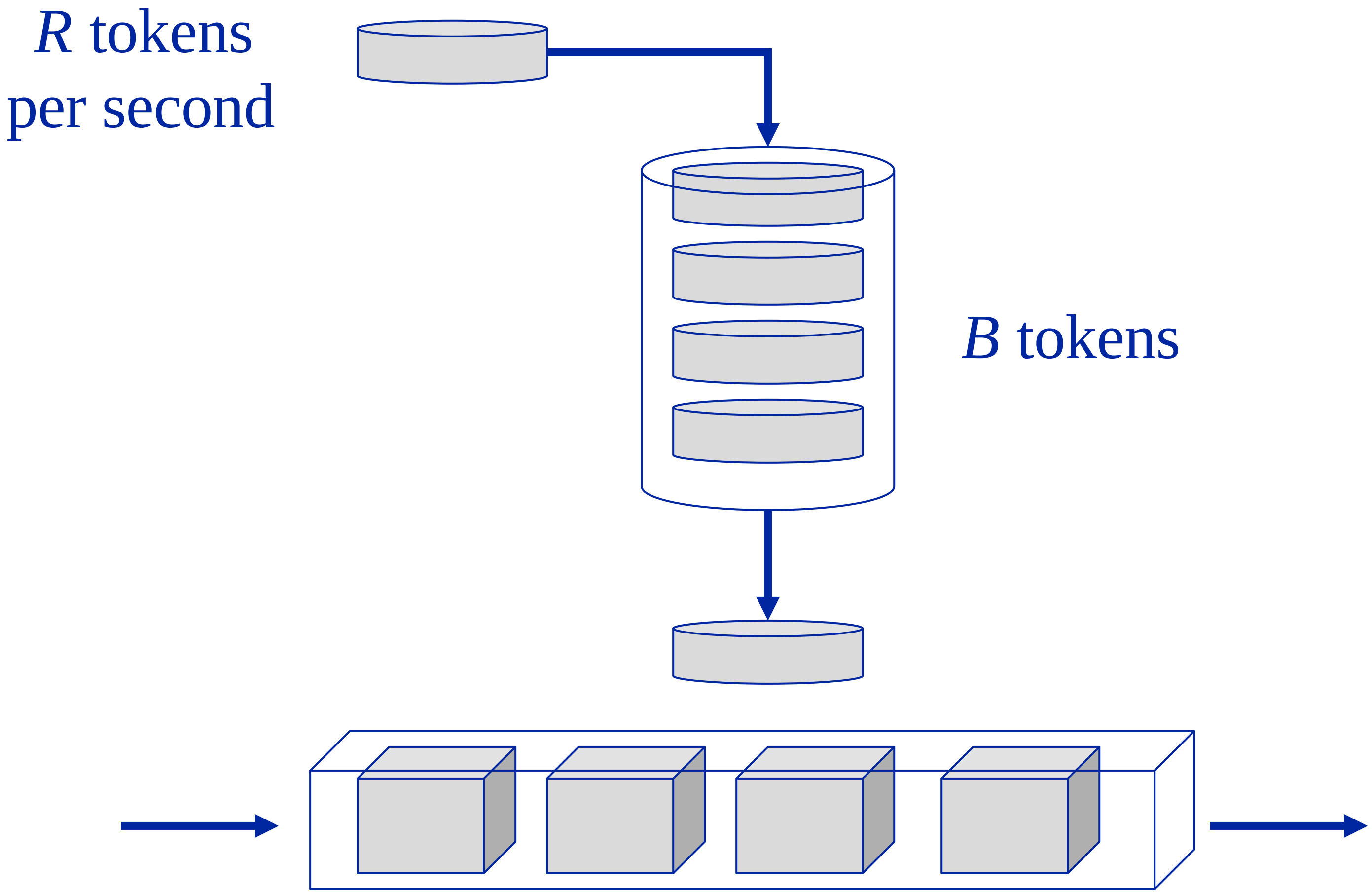
Leaky Bucket



Token Bucket

- A token is required to sent a packet
  - + a bucket is used, which can hold *B* tokens
  - + *R* tokens enter the bucket per second
- Tokens are saved in bucket if they are not used
  - + bursts are allowed to certain limit

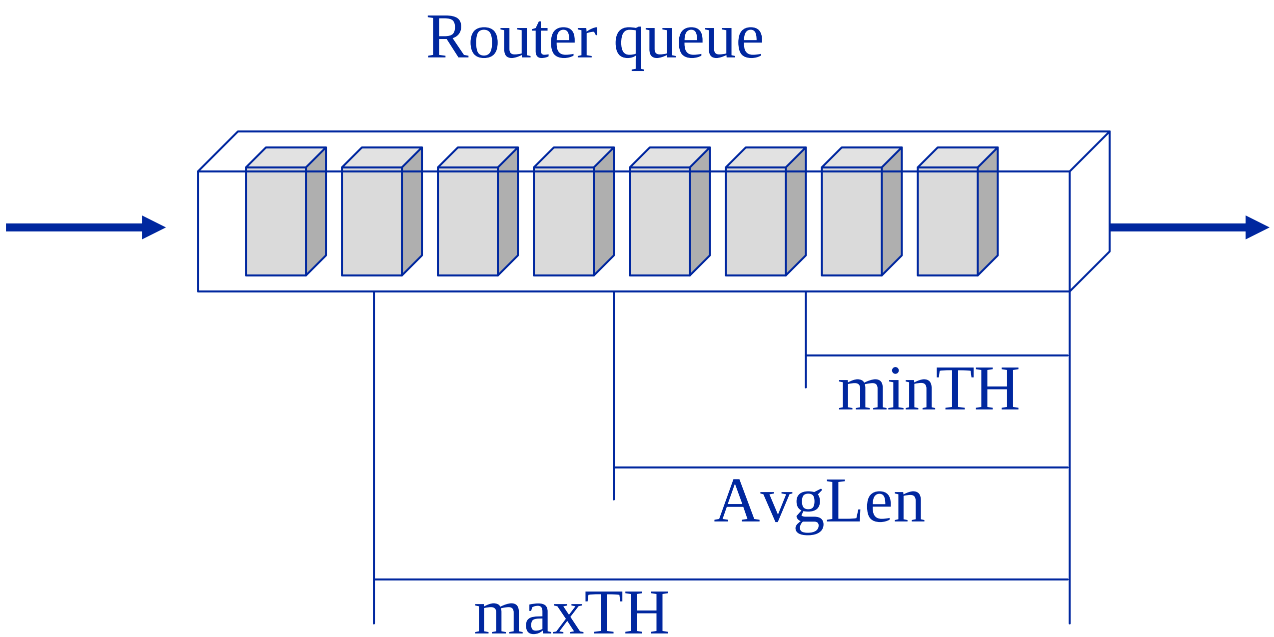
Token Bucket



Random Early Detection (RED)

- The objective is to prevent TCP/IP traffic from stalling
  + the packets are discarded with larger likelihood, when the amount of traffic grows
- Suits well with TCP protocol
  + individual TCP protocols drop speed, when packets are lost
  + the effect doesn’t happen at the same time

RED



Conclusion

- Routers (and switches) have big influence on the QoS properties of the network
- This can be utilized in the implementation
  + different queues
- Individual traffic flows can be shaped
  + leaky bucket, token bucket, RED

Integrated Services

- Integrated Service Architecture work was started 1994
- Designed to provide a set of extensions to the best-effort traffic model of Internet
- Basic underlying Internet architecture should not be modified
- Similar to the ATM model of QoS

Objectives

- Define the services to be provided
- Define the interfaces for
    - + Application service
    - + Router scheduling
    - + Link-layer
- Define router validation requirements

Implementation

- Real-time applications require resource reservation
- Reservation requires admission control
- Five key components
  + QoS requirements
  + resource-sharing requirements
  + allowance for packet dropping
  + provision for usage feedback
  + resource reservation protocol (RSVP)

QoS Requirements

- Focus on real-time QoS classes
- Latency and jitter are most important issues
- Two QoS-classes
  + Controlled load service
  + Guaranteed QoS Service Class

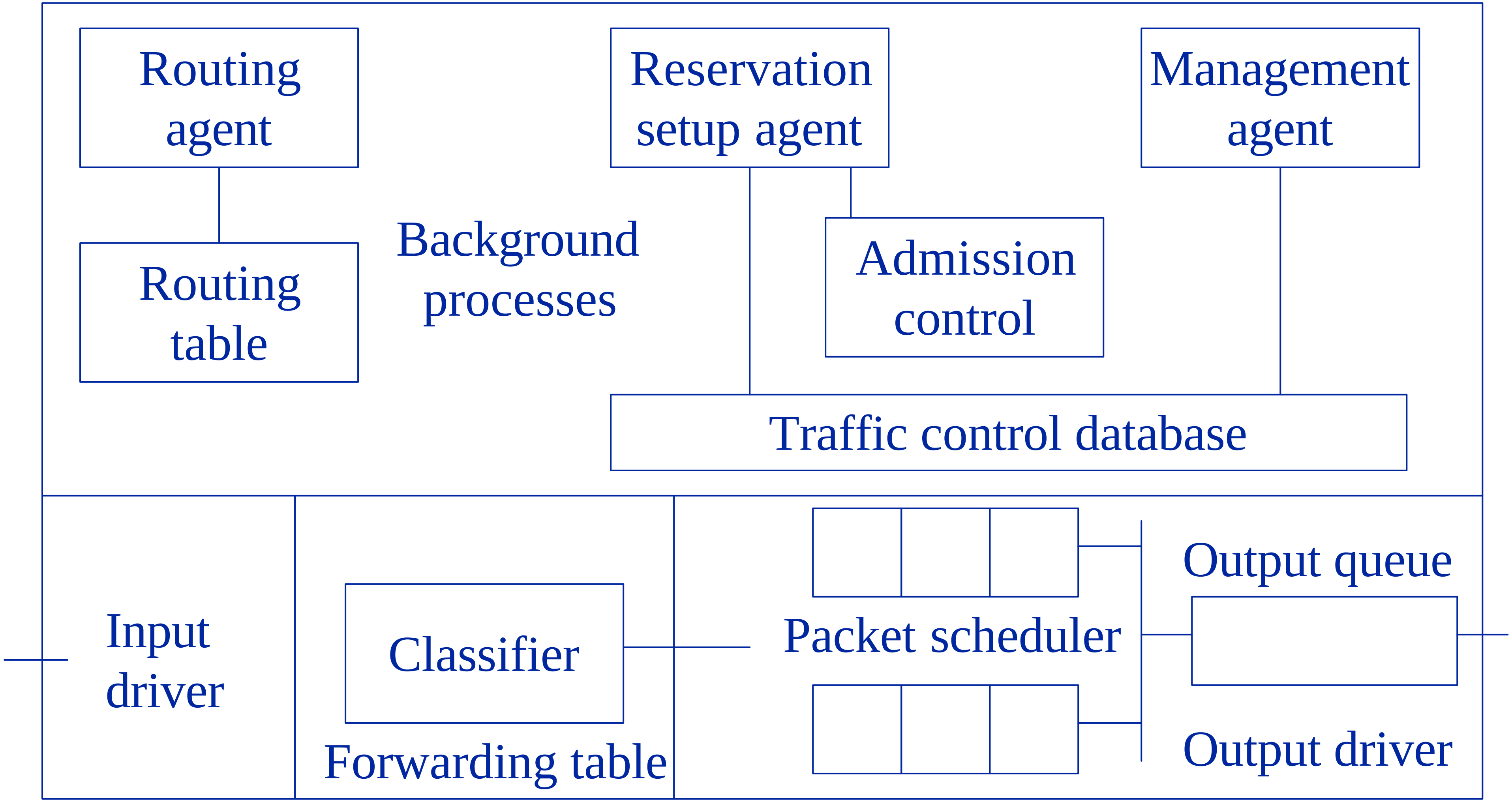
Controlled Load Service

- Approximates traditional best-effort services in unloaded condition
  - + Better that best-effort
- Uses token bucket filter
- Each node handling the controlled load service request ensures that sufficient resources are available

Guaranteed QoS Service Class

- Bandwidth and delay guarantee
- Also uses the token bucket filter
- Measures end-to-end QoS
- Calculates end-to-end and hop-by-hop error terms
  + Cumulative delay (measured in bytes)
  + Delay caused by a node (measured in microseconds)

Reference model



Resource Sharing Requirements

- Allocation for network resources is accomplished on a flow-by-flow basis
  - + Different network protocols (e.g., IP, IPX, SNA)
  - + Different services within the same protocol suite (e.g., Telnet, FTP, SMTP)
- Different traffic flows should not unfairly utilize more than their fair share of network resources

Allowance for Packet Dropping

- Traffic control is provided by dropping packets
- Packets may be preemptable or subject to drop
- Similar to Random Early Detection (RED)

Conclusions

- Scalability is a big issue
  + What is ISP-router has 10 000 flows?
- Lacks security
  + Service attacks
- Special Link-Layer
  + ATM virtual circuit

Differentiated Services Objectives

- Solution has to scale
  - + individual micro-flows are aggregated into a single larger aggregate flow
  - + the aggregate flow receives special treatment
- Applicable to all applications
  - + no special control protocol (i.e., RSVP)
  - + no new application programming interfaces
- Gigabitrate operation
  - + 2.4 and 10 Gbps line rates are coming
- ISPs want to offer portfolio of service
  - + versioning
  - + QoS classes

Service Classes

- Individual microflows are classified at the edge of the network
- Several unique service classes
  - + E.g., Gold, Silver, Bronze
- Per-class service is applied in the middle of network
- Classification is based on one or more fields in the packets

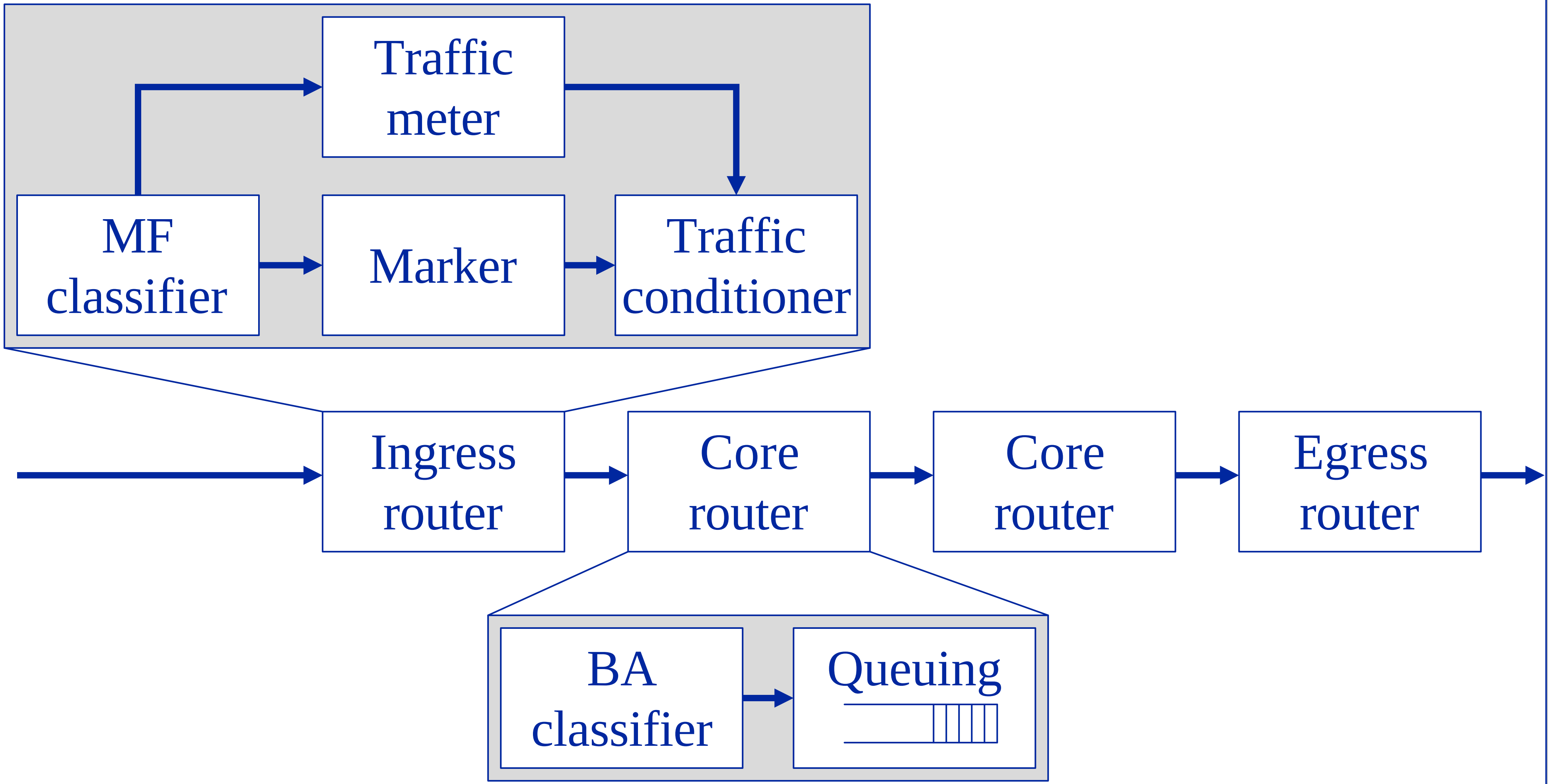
Components

- DS-Field: denotes the service the packet should receive
  - + IPv4: Type-of-service
  - + IPv6: Traffic class
- Per-hop behavior (PHB): defines the service the packet receives at each hop
- Behavior aggregate (BA): group of similar packets

Components (cont.)

- Boundary router: positioned at the edge of the DiffServ-capable network
  - + Packet classification
  - + Metering
  - + Marking
  - + Traffic conditioning
- Interior router: core switches or routers that provide PHB

Reference Model



Per-hop Behavior

- IETF DiffServ Working Group has defined two PHBs:
  + Expedited forwarding (EF)
  + Assured forwarding (AF)

Expedited Forwarding (EF)

- Supports low loss, low delay, and low jitter connections
- Point-to-point virtual leased line
- Peak bandwidth
- Packets must spent minimum time in router queues
- Traffic is conditioned to the peak rate

Assured Forwarding (AF)

- Four relative classes of service
  - + just distinct classes
- Each service class has three levels of drop precedence
  - + high precedence packets are dropped before low precedence packets
- In total, twelve combinations

Open Questions

- How network policies are managed?
  - + Manual configuration
  - + Simple Network Management Protocol (SNMP)
  - + Lightweight Directory Access Protocol (LDAP)
  - + Common Open Policy Server (COPS)
- How to extend across ISP boundaries?
  - + Bilateral agreements
  - + Bandwidth brokers