QoS for Real Time Applications over Next Generation Data Networks

Project Status Report: Part 1
June 2, 2000

http://www.engr.udayton.edu/faculty/matiquzz/Pres/QoS.pdf

University of Dayton

Mohammed Atiquzzaman

Jyotsna Chitri

Faruque Ahamed

Hongjun Su

Haowei Bai

Ohio State University

Raj Jain

Mukul Goyal

Bharani Chadavala

Arindam Paul

Chun Lei Liu

Wei Sun

Arian Durresi

NASA Glenn

Will Ivancic

New Address: Raj Jain, Washington University in Saint Louis,
jain@cse.wustl.edu, http://www.cse.wustl.edu/~jain

Outline of Talk

- Present state of the Interent.
- QoS approaches to future data networks.
- Research Issues.
- Progress to date:
  - Task 1: DS over ATM
  - Task 2: IS over DS
  - Task 3: ATN
  - Task 4: Satellite networks
  - Task 5: MPLS
- Conclusions.

Current Internet

- TCP/IP glues together all the computers in the Internet.
- TCP/IP was designed for terrestrial networks.
- TCP/IP does not
  - offer QoS to real time applications, or
  - perform well in long delay bandwidth networks.

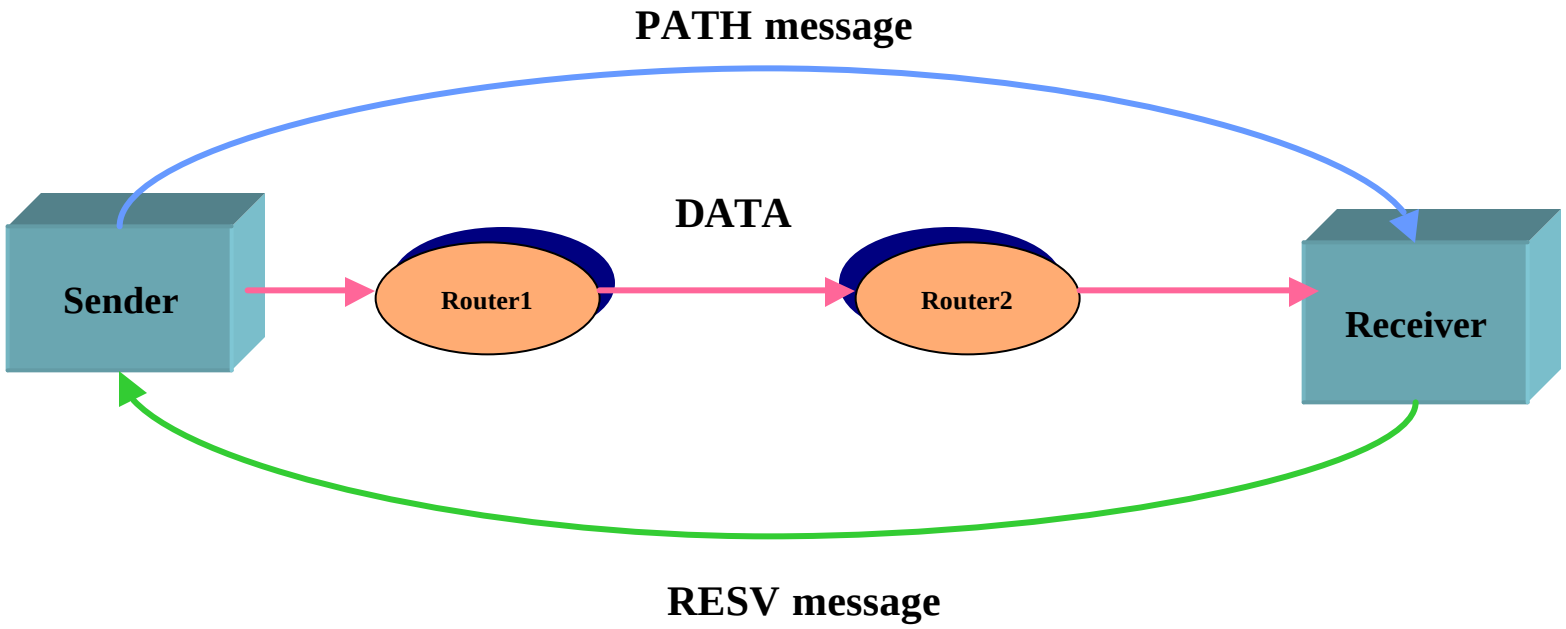
Efforts to provide QoS in Internet

- Integrated Services (IS)
- Differentiated Services (DiffServ)
- Explicit Congestion Notification (ECN)
- Multiprotocol Label Switching (MPLS)
- Asynchronous Transfer Mode (ATM)

Integrated Services

- RSVP to reserve resources during connection setup.
- End-to-end QoS guarantees.
- A router has to keep information about all connections passing through the router.
- Gives rise to scalability problem in the core routers.

RSVP Signaling



RSVP Signaling

- Reserves a portion of link bandwidth in each router
- The sender sends a PATH message with resource requirements for a flow.
- Receiver responds with a RESV message
- Each router processes the RESV to reserve the required resources requested by the sender.
- Routers can modify the QoS parameters of the RESV message if enough resources are not available to meet the requirements.
- Each router in the entire path confirms the end-to-end reservation for the flow.

IS Service Classes

- **Guaranteed Load Service**
  - **Low end-to-end delay, Jitter, Loss.**
  - **Highest priority service.**
- **Controlled Load Service**
  - **Network should forward the packets with queuing delay not greater than that caused by the traffic's own burstiness (RFC 2474).**
  - **Performance similar to that of an unloaded network.**
  - **Traffic specifications from the Tspec.**
- **Best Effort**

Differentiated Services

- Similar traffic are grouped into classes.
- Resources reserved for classes.
- QoS provided to classes.
  - QoS to individual connections is an open research issue.
- QoS maintained by:
  - Classification
  - Traffic policing
    - Metering, dropping, tagging
  - Traffic shaping
- Per Hop Behavior (PHB)
  - Specifies QoS received by packets i.e. how packets are treated by the routers.

Asynchronous Transfer Mode

- Strong QoS guarantees; suitable for real time applications.
- High cost prohibits use at the edge network or to the desktop.
- Currently used at the core of the Internet.

Next Generation Internet

- Routers at the edge network will not need to carry too many connections
  - IS can be used at the edge network.
- Core network needs to carry lot of connections.
  - Combination of DS, ATM and MPLS at the core.
- Satellite/Wireless links
  - Remote connectivity and mobility.

Research Issues

- Service mapping between networks.
- Loss and delay guarantees.
- Interoperability among edge and core technologies.
- Interoperability with Aeronautical Telecommunications Network (ATN).
- Operation in satellite environment having high delay and loss.

Prioritized Early Packet Discard

Asynchronous Transfer Mode (ATM)

- **Service Classes**
  - **Constant Bits Rate (CBR)**
  - **Available Bit Rate (ABR)**
  - **Unspecified Bit Rate (UBR)**
- **CLP in cell header**
  - **Determines loss priority of packets**

Differentiated Services

- **Service Classes**
  - **Premium Service: emulates leased line**
  - **Assured Service**
  - **Best Effort Service**
- **Various levels of drop precedence.**
  - **Need to be mapped to ATM when running DS over ATM.**
  - **Could be possible mapped to the CLP bit of ATM cell header.**

DS over ATM

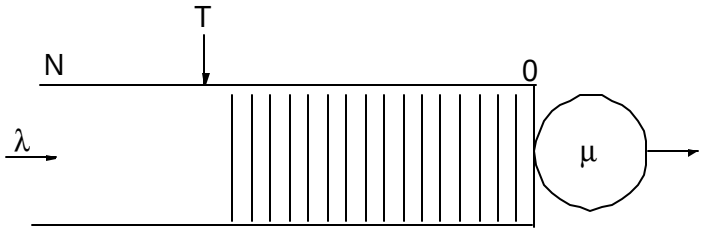
- Possible Service Mappings
  - Premium Service → ATM CBR service.
  - Assured Service → ATM UBR service with CLP=0
  - Best Effort → ATM UBR service with CLP=1
- DS packets are broken down into cells at the DS-ATM gateway
  - Drop precedence mapped to CLP bit
- Buffer Management at ATM switches
  - Partial Packet Discard (PPD)
  - Early Packet Discard (EPD)

Prioritized EPD

- DS service classes can use the CLP bit of ATM cell header to provide service differentiation.
- EPD does not consider the priority of cells.
- Prioritized EPD can be used to provide service discrimination.
- Two thresholds are used to drop cells depending on the CLP bit.

Buffer Management Schemes

EPD



•QL < T

Accept all packets.

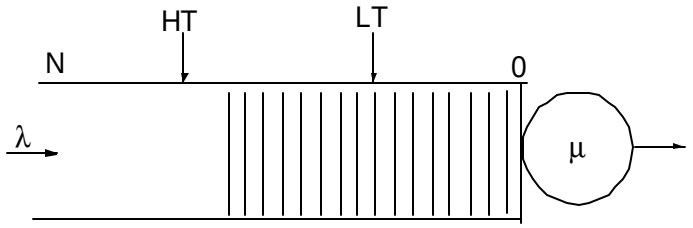
•T ≤ QL < N

Discard all new incoming packets.

•QL ≥ N

•Discard all.

PEPD



•QL <LT

Accept all packets.

•LT ≤ QL < HT

Discard all new low priority packets.

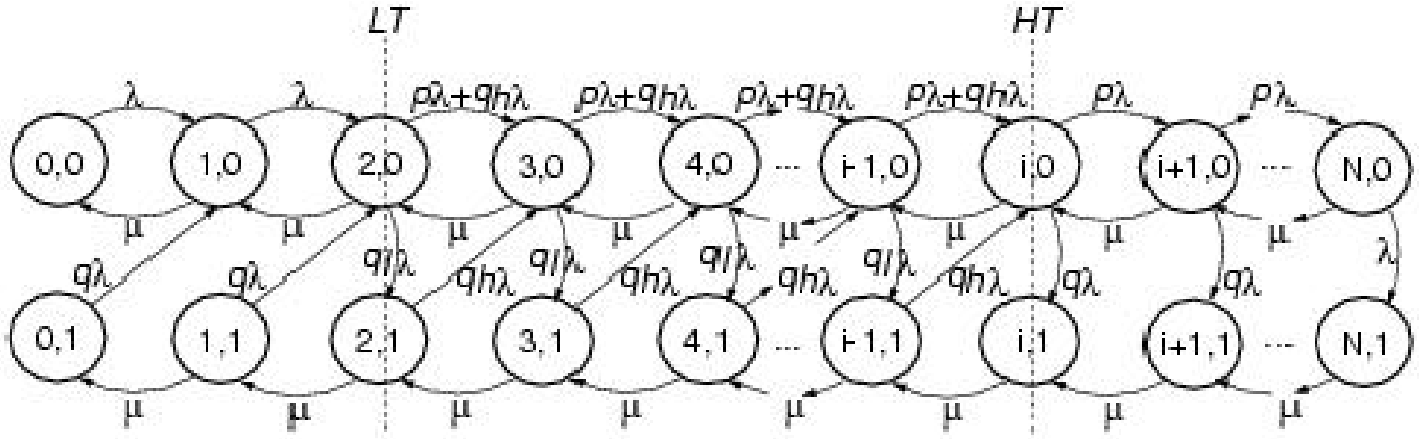
•HT ≤ QL < N

Discard all new packets

QL ≥ N

•Discard all packets

Steady State Diagram



Steady State Equations

$$\lambda P_{0,0} = \mu P_{1,0}$$

$$q\lambda P_{0,1} = \mu P_{1,1}$$

$$(\lambda + \mu)P_{i,0} = \lambda P_{i-1,0} + \mu P_{i+1,0} + q\lambda P_{i-1,1} \qquad 1 \le i \le LT$$

$$(\lambda + \mu)P_{i,0} = (\lambda p + qh\lambda) P_{i-1,0} + \mu P_{i+1,0} + qh\lambda P_{i-1,1} \qquad LT < i \le HT$$

$$(\lambda + \mu)P_{i,0} = p\lambda P_{i-1,0} + \mu P_{i+1,0} \qquad HT < i < N$$

$$(\lambda + \mu)P_{N,0} = p\lambda P_{N-1,0}$$

$$\mu P_{N,1} = \lambda P_{N,0}$$

$$\mu P_{i,1} = q\lambda P_{i,0} + \mu P_{i+1,1} \qquad HT \le i < N$$

$$(\mu + qh\lambda)P_{i,1} = q\lambda (1-h) P_{i,0} + \mu P_{i+1,1} \qquad LT \le i < HT$$

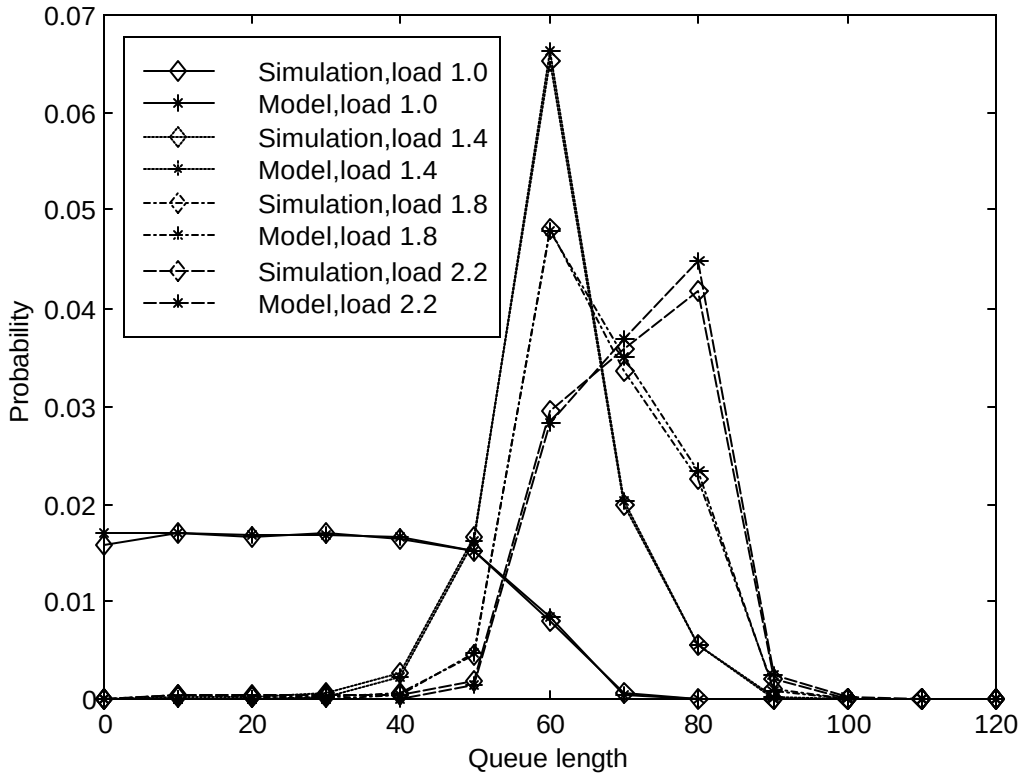
$$(\mu + q\lambda)P_{i,1} = \mu P_{i+1,1} \qquad 0 < i < LT$$

$$\sum_{i=0}^{N} (P_{i,0} + P_{i,1}) = 1$$

Goodput

$$G_h = \frac{\sum_{n=1}^{\infty} nP(W = n, V = 1, U = 1)}{\sum_{n=1}^{\infty} nP(W = n, U = 1)}$$

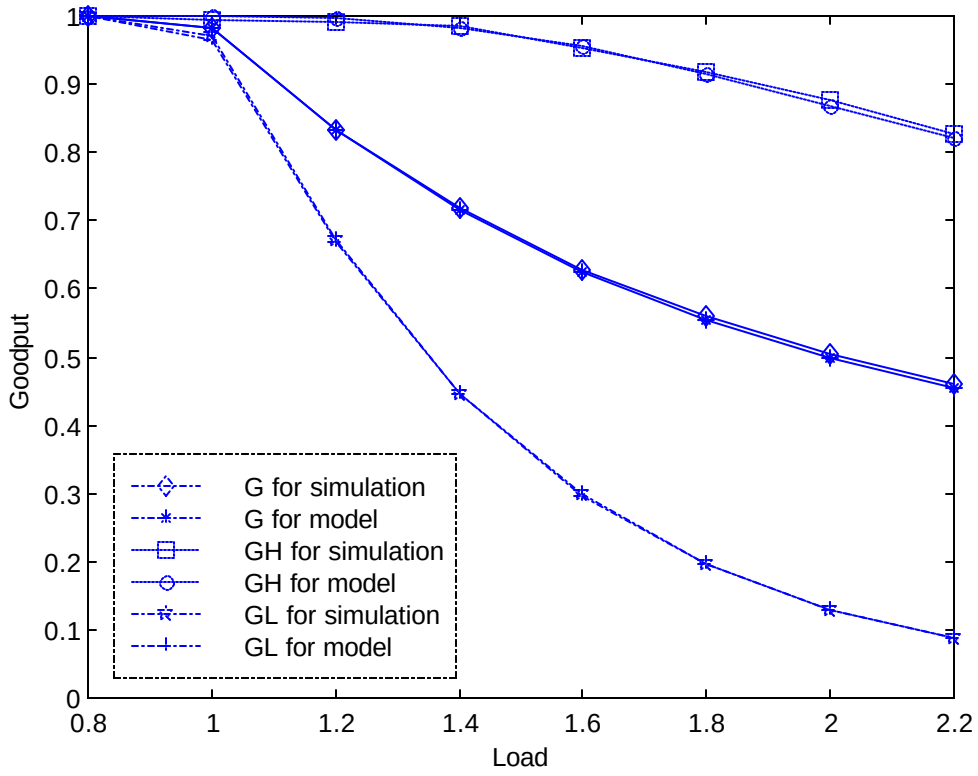
Queue Occupancy



***Simulation:* N=120, LT=60, HT=80, h=0.5, q=1/6.**

Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

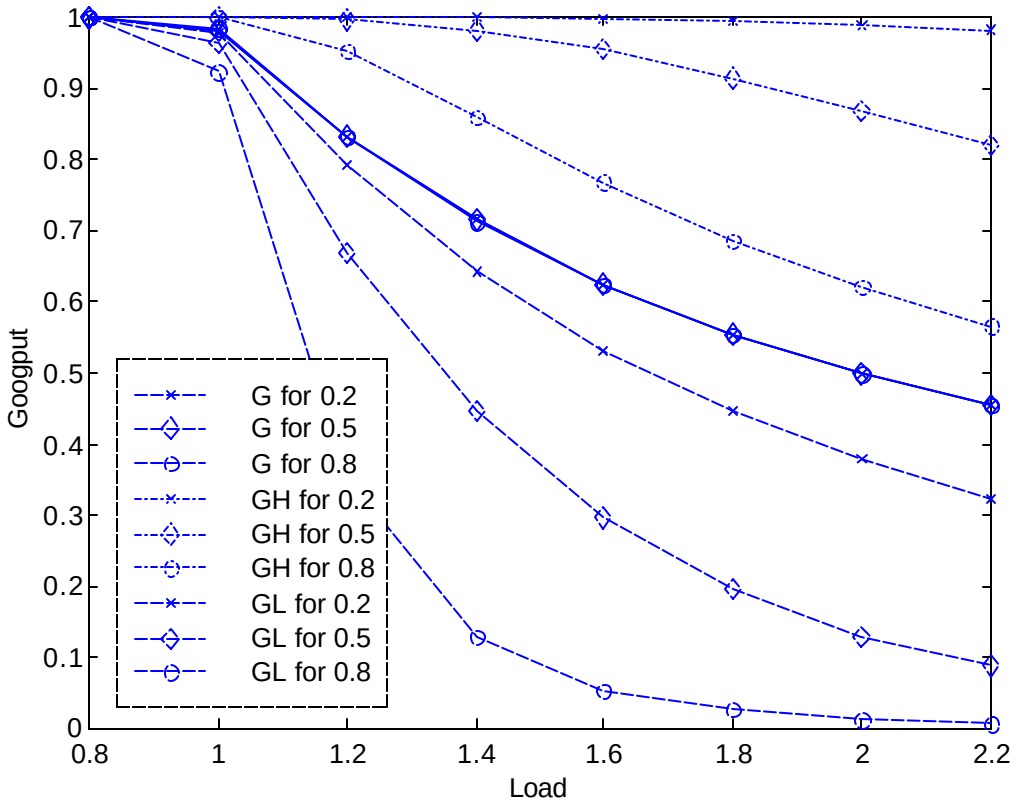
Goodput versus load for *h*=0.5



Simulation: N=120, LT=60, HT=80, q=1/6.

Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

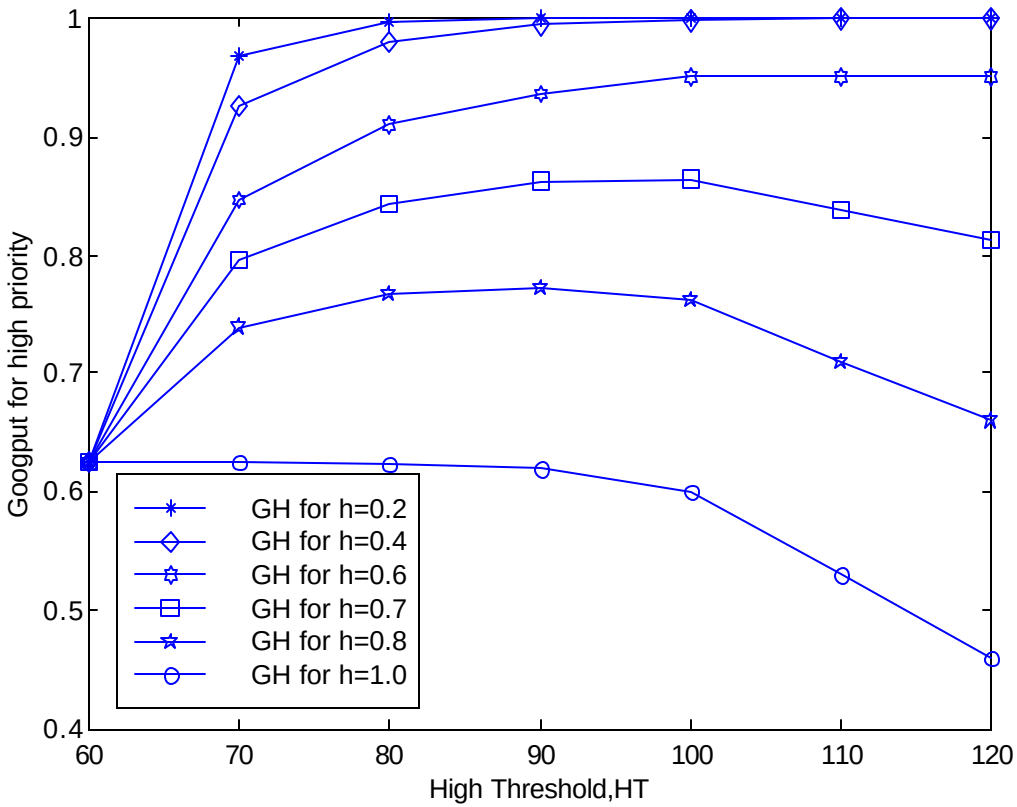
Goodput versus load for *h*=0.2, 0.5, 0.8



Simulation: N=120, LT=60, HT=80, q=1/6.

Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

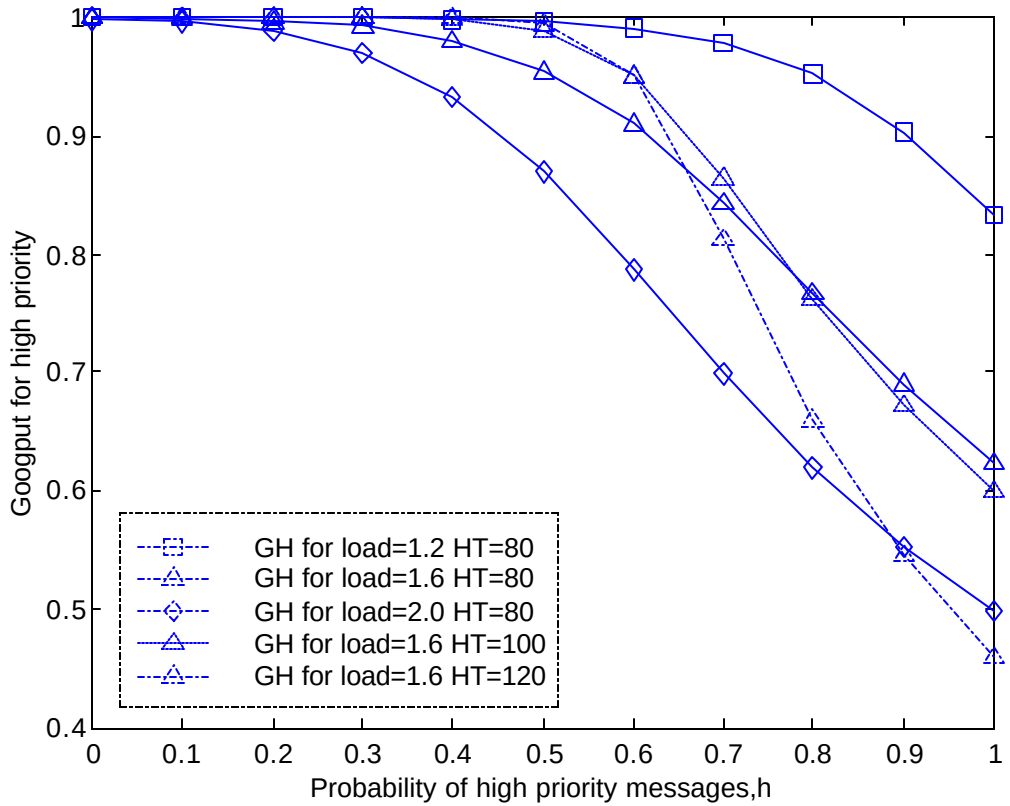
Goodput for high priority vs. HT



Simulation: LT=60, *q*=1/6

Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

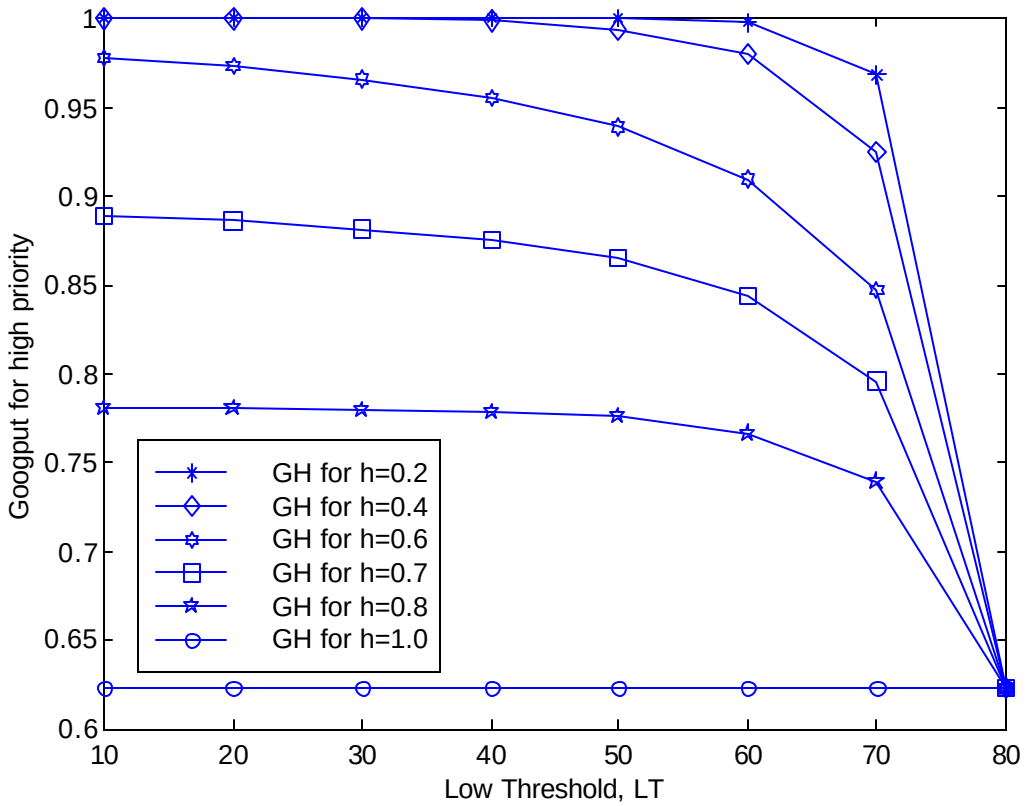
Goodput of high priority vs. *h*



Simulation: LT=60

Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

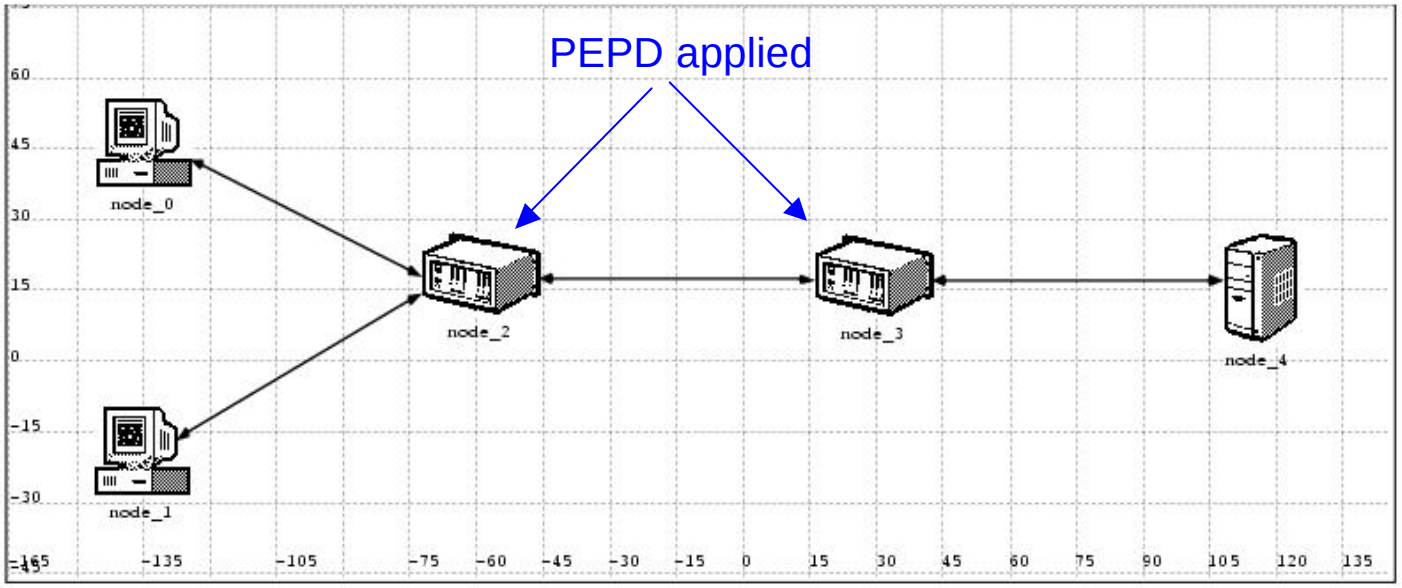
Goodput for high priority versus *LT*



Simulation: N=120, HT=80, load=1.6, q=1/6.

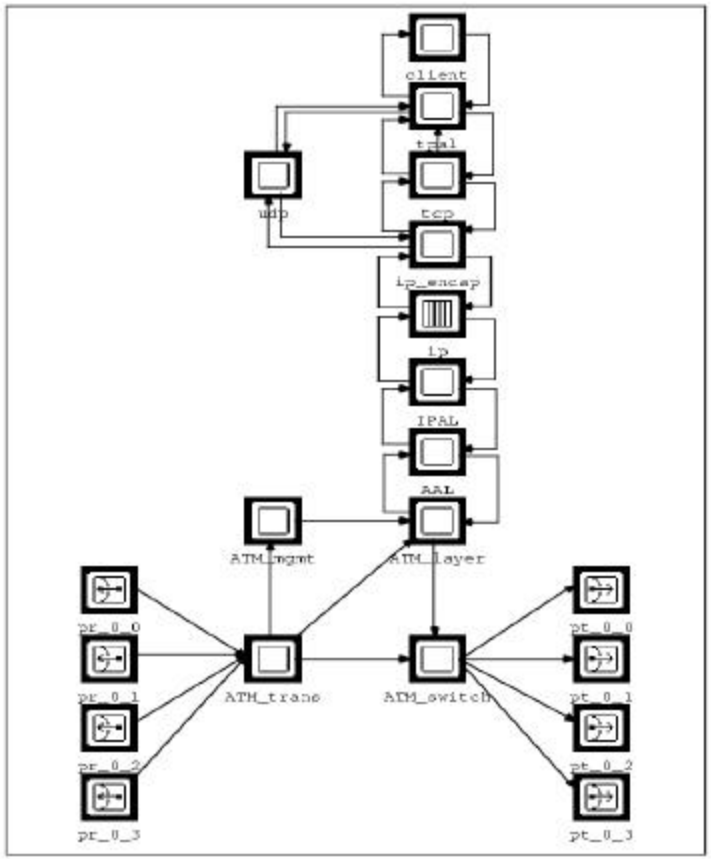
Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

OPNET Simulation Configuration



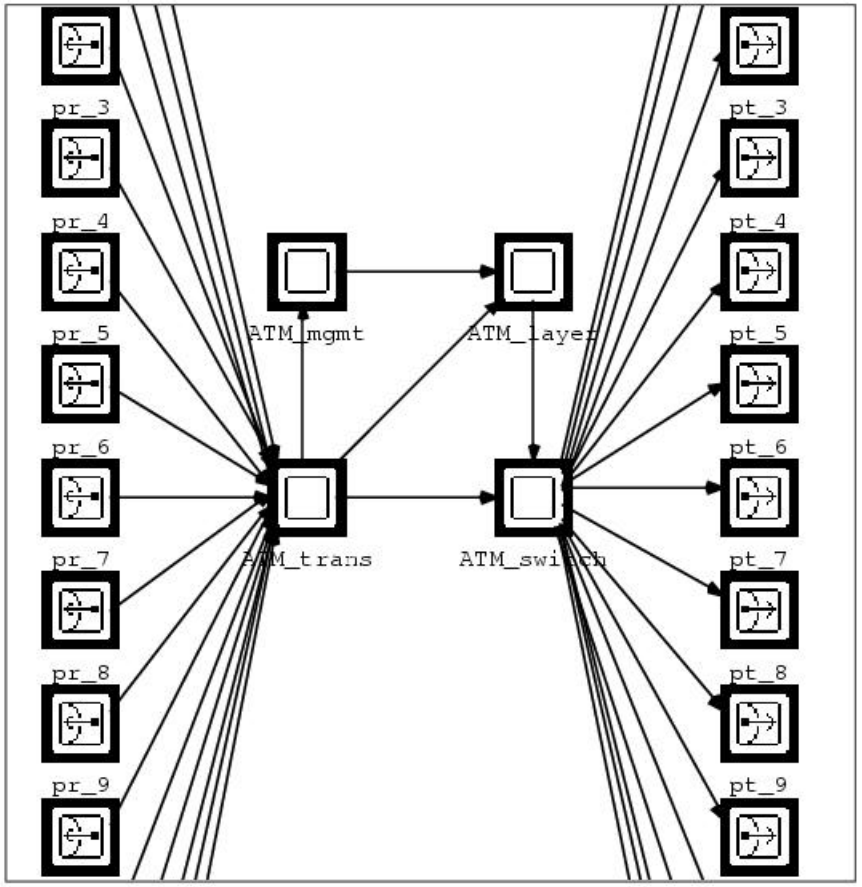
DS-ATM Protocol Stack

- AAL Layer marks the End of Packet.
- ATM_layer changes the CLP bit depending on the packet of the DS service.

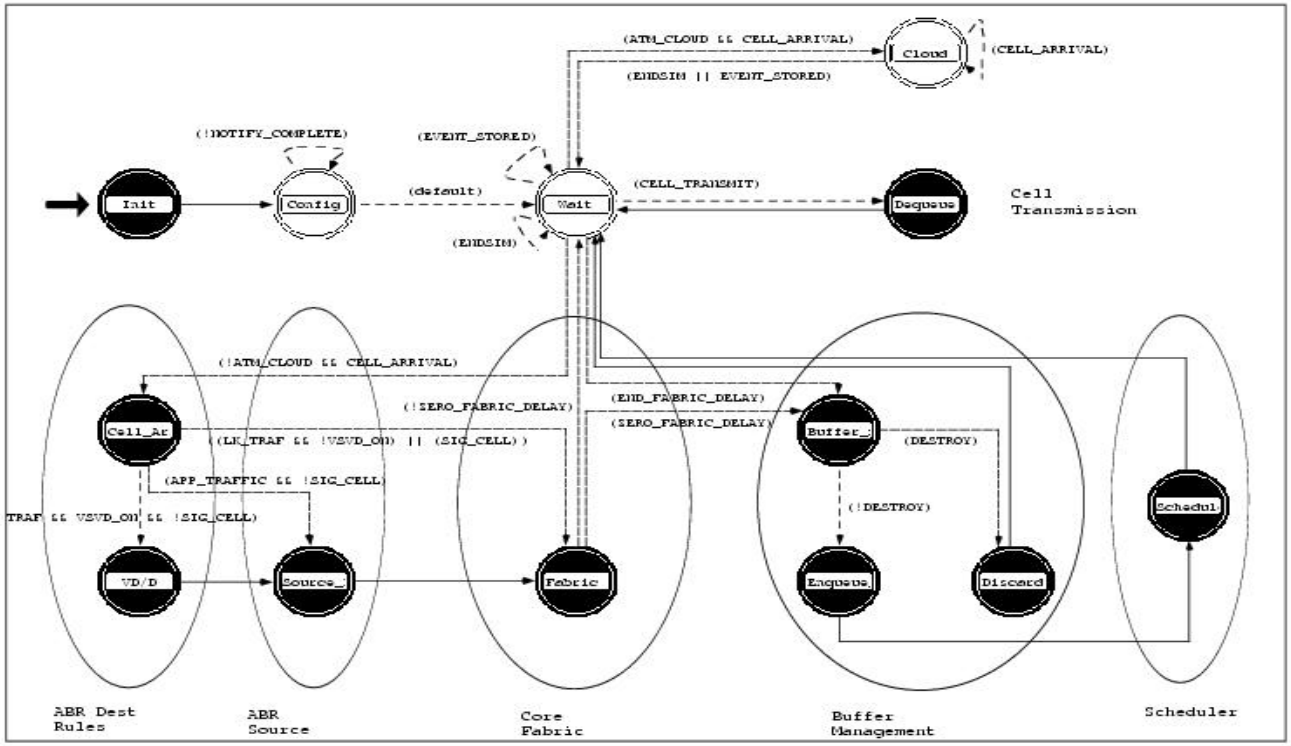


ATM Switch Node

- Support service differentiation in the ATM switch buffer.
- Change the buffer management scheme in the ATM_switch process to Prioritized EPD.



ATM_Switch Process



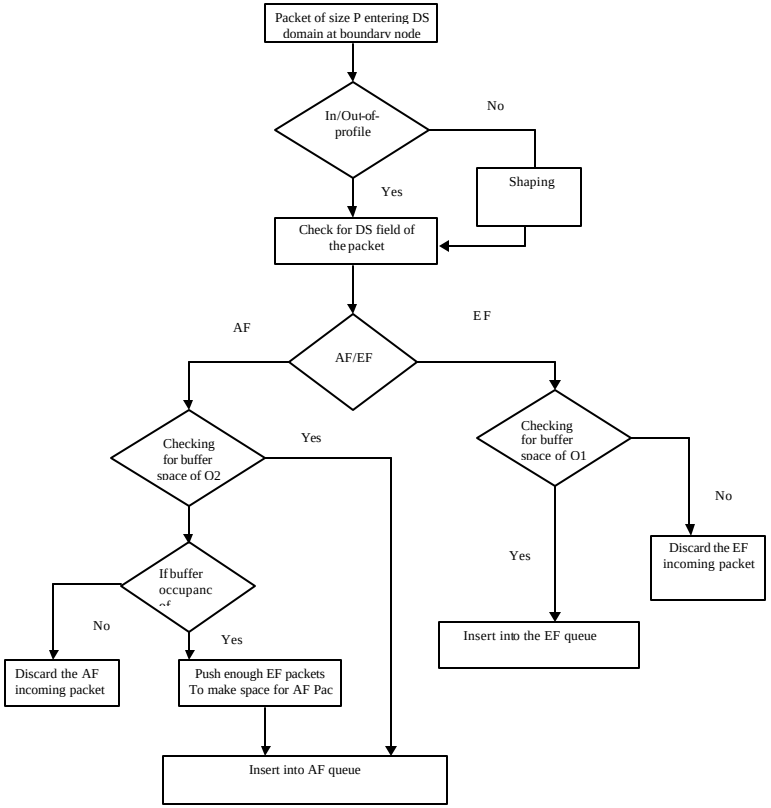
Implements the PEPD buffer management to support service differentiation.

Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

Mapping of

IS over DS

Traffic entering DS domain



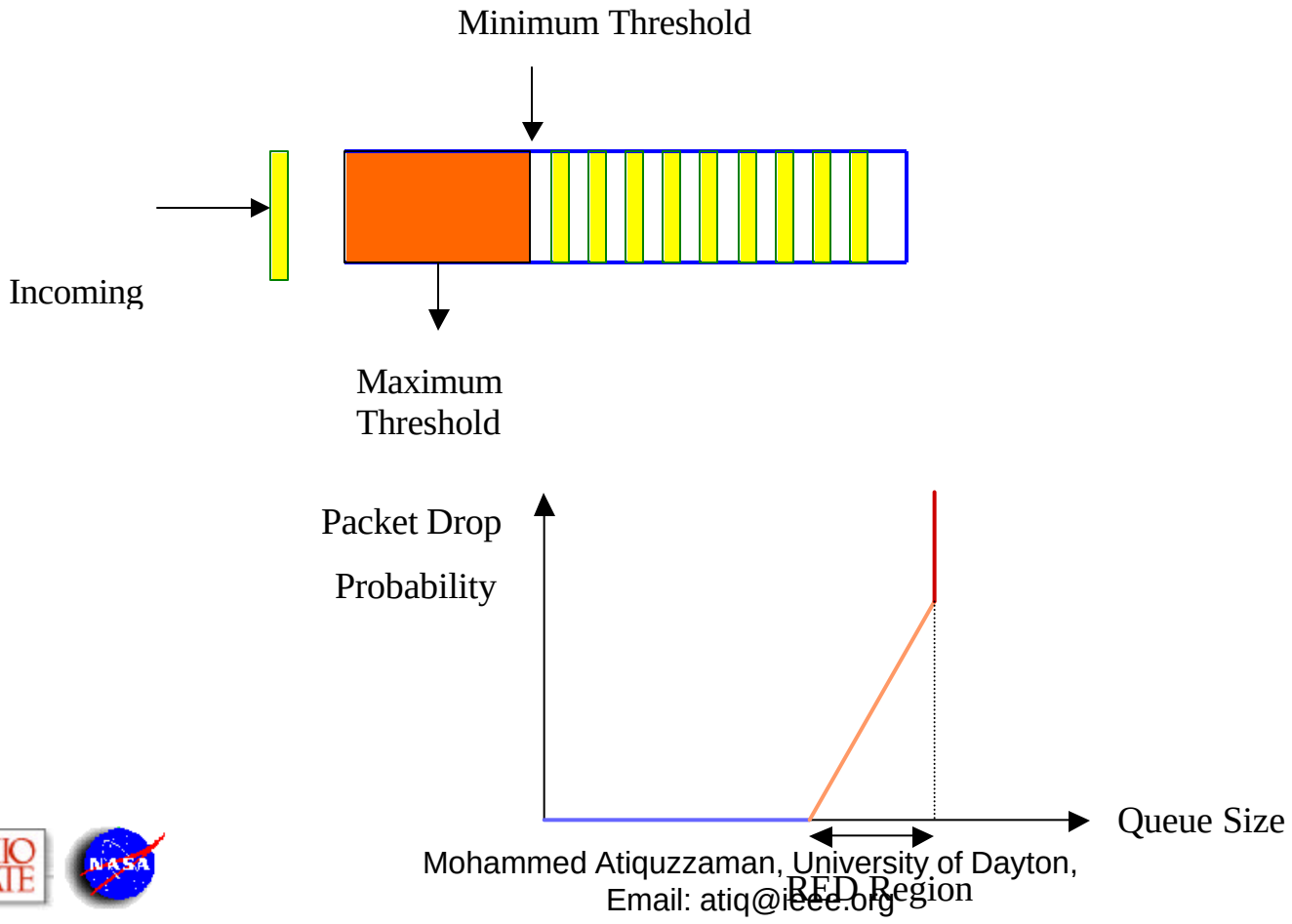
Differentiated Services

- ***Classification***: **Based on IP header field classifies into BA to receive particular per hop behavior (PHB)**
- ***Metering***: **Measuring the traffic against token bucket to check for resource consumption**
- ***Shaping***: **Treatment of out-of-profile traffic by placing it in a buffer.**
- ***Dropping***: **Non-conformant traffic can be dropped for congestion avoidance**
- ***Admission Control***: **Limiting the amount of traffic according to the resources in the DS domain.**
  - **Implicit Admission Control: Performed at each router**
  - **Explicit Admission Control : Dynamic resource allocation by a centralized bandwidth broker**

Various PHB's

- Expedited Forwarding(EF PHB)
- Assured Forwarding (AF PHB)
- Best Effort (Default)

Queue Implementation (RED)



QoS Specifications

- **Bandwidth:**
- **Latency:**
- **Jitter:**
- **Loss:**

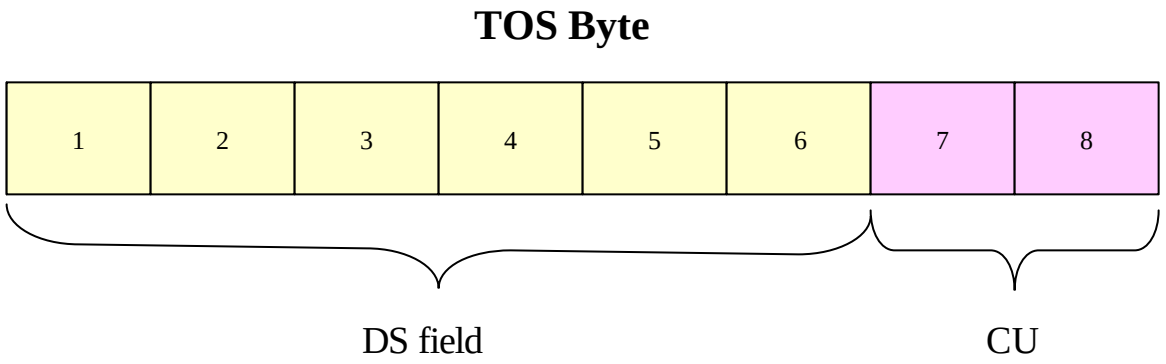
Service Mapping from IS-DS

- Provide different levels of service differentiation.
- Provide QoS to multimedia and multicast applications.
- Scalability in terms of resource allocation.
- There is no over head due to per flow state maintenance at each router.
- Forwarding at each router according to the DSCP code.
- PHB's along the path provide a scheduling result approximating the QoS requirements and results in IS

Integrated Service	Differentiated Service
Guaranteed Load	Expedite Forwarding
Controlled Load	Assured Forwarding
Best effort	Default best effort

DS functionality

- Per Hop behavior (PHB)
- Behavior Aggregate (BA)
- Differentiated Services Code Point (DSCP)



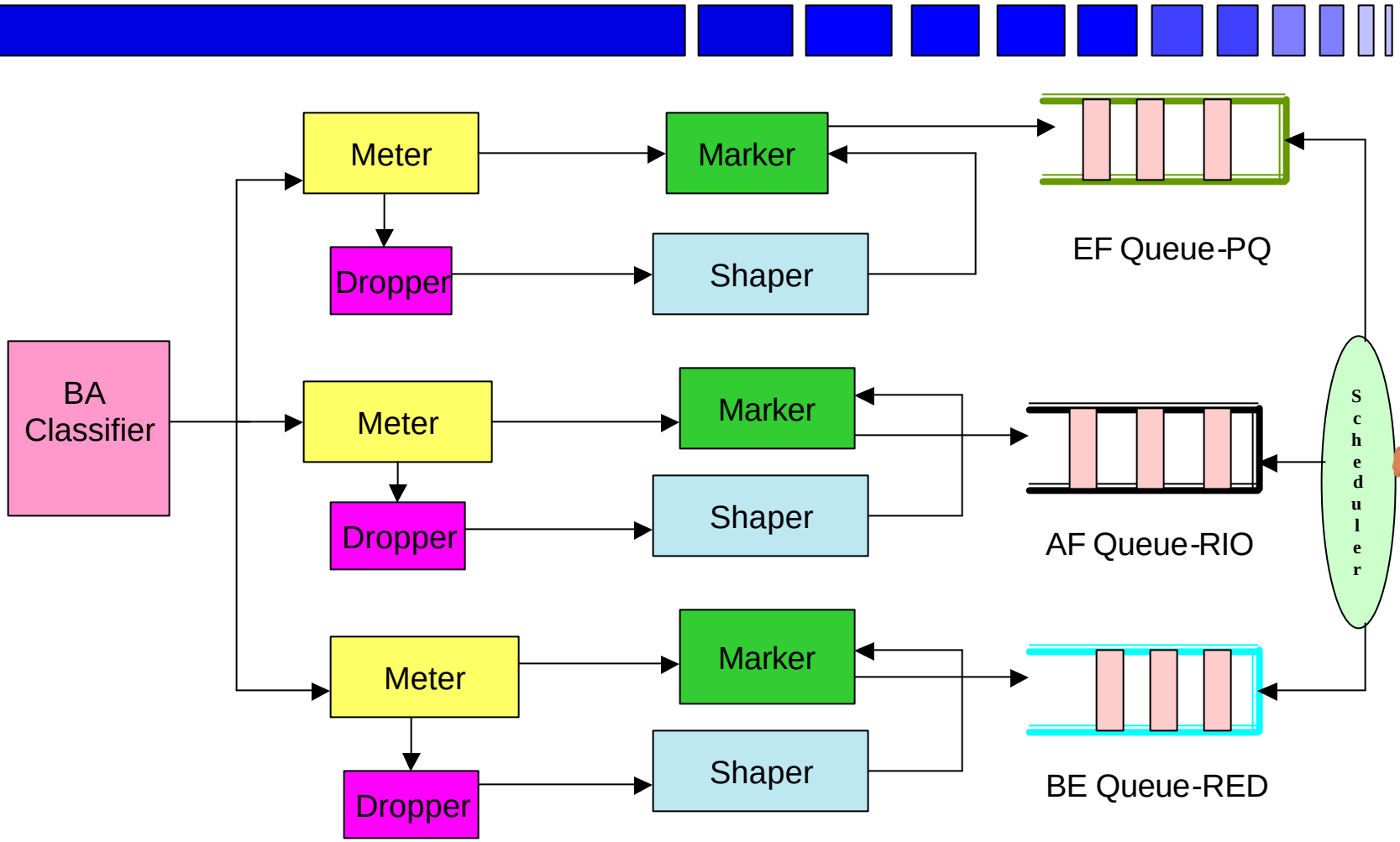
Guaranteed load - EF PHB

- Guaranteed traffic performance can be met effectively using the EF PHB with proper policing and shaping functions.
- Shaping Delay
- Queuing Delay
- Packets in the Scheduler

Controlled Load - AF PHB

- Classified into delay classes based on the B/R ratio of Tspec for each delay class; Aggregate Tspec is constructed for all the admitted traffic.
- For each delay class, police the traffic against a token bucket derived above.
- Size of the queue is set to limit the queuing delay of AF requirement.
- RIO dropping parameters are set according to the drop precedence of the AF class.
- AF instance service rate is set to bandwidth sufficient enough to meet the delay and loss requirements of the CL traffic.
- Bandwidth distributed between AF and BE to prevent the BF from starvation.
- Scheduling done with WFQ (Weighted Fair Queuing) or WRR (Weighted Round Robin)

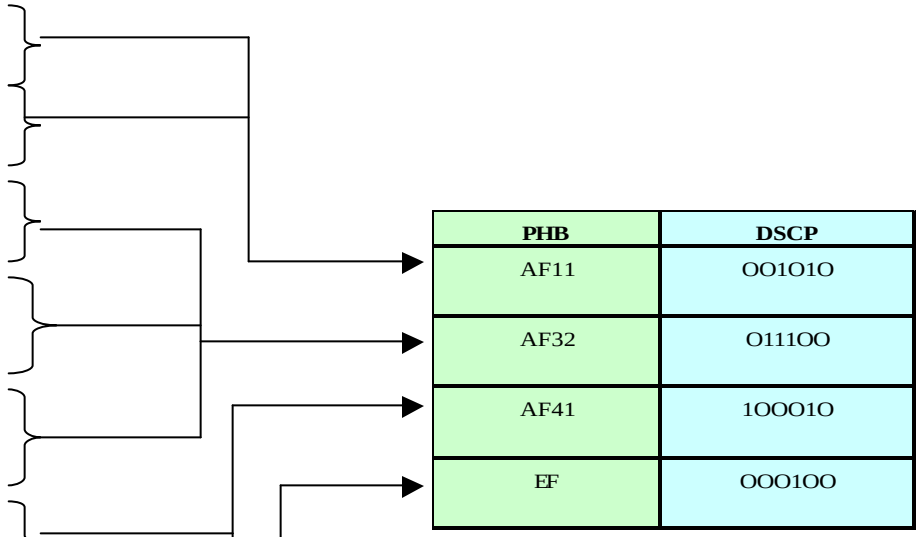
Traffic Conditioning at DS Boundary



Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

Mapping Table for IS-to-DS

Flow Id	T Spec Parameters
1	R = 400 P = 500 B = 700
2	R = 450 P = 550 B = 750
3	R = 500 P = 600 B = 800
4	R = 550 P = 650 B = 850
5	R = 600 P = 700 B = 900
6	R = 650 P = 750 B = 950
7	R = 700 P = 800 B = 1000
8	R = 750 P = 850 B = 1050
9	R = 800 P = 900 B = 1100
10	R = 850 P = 950 B = 1150



PHB	DSCP
AF11	OO1O1O
AF32	O111OO
AF41	1OOO1O
EF	OOO1OO

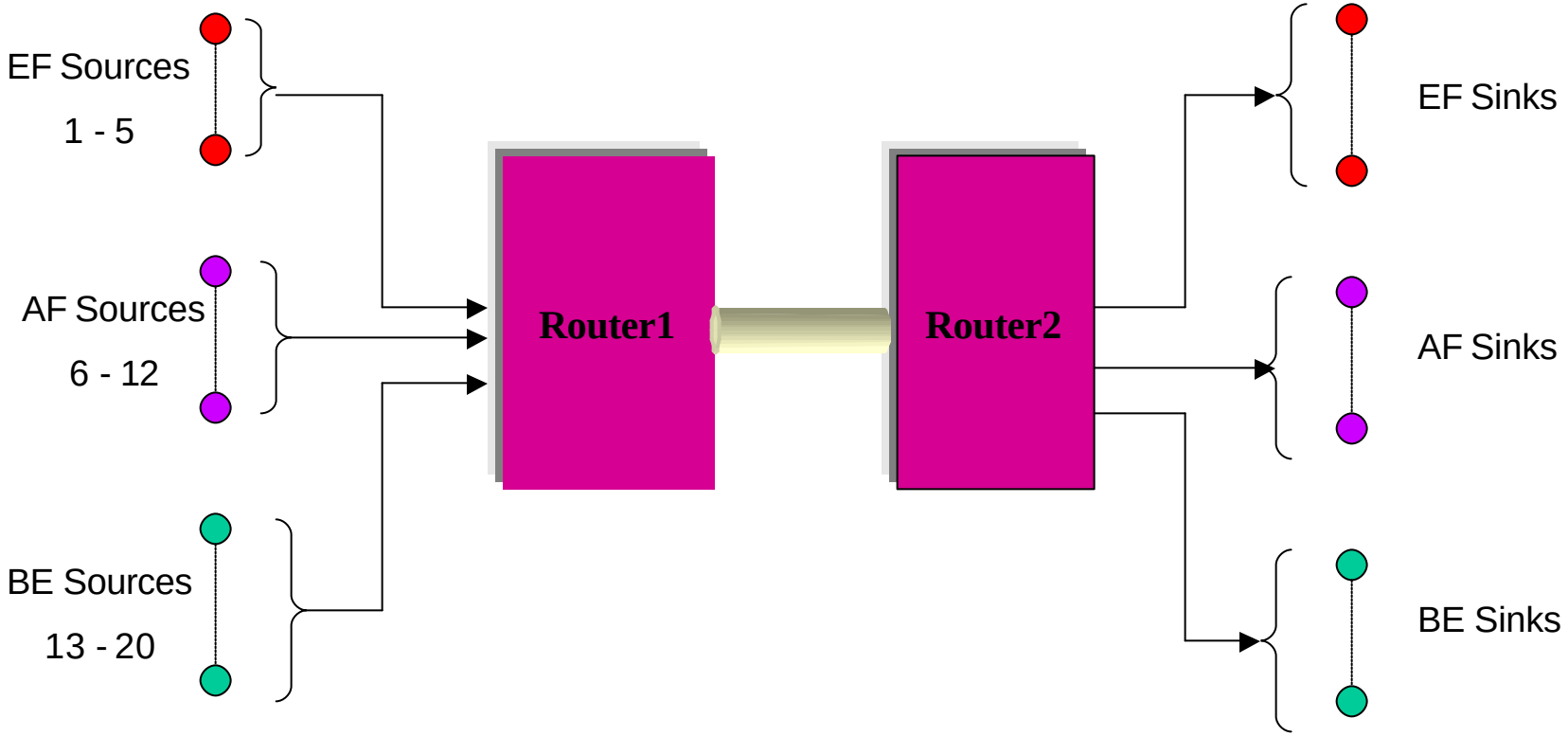
Mapping of IS to DS

- Tspec parameters indicating resource reservation taken from RSVP signaling.
- Table entry contains Tspec parameters, flow IDs, PHB groups and DSCP values.
- Measures actual traffic flow rate against a token bucket according to the initial stored table entry.
- If the traffic is in-profile with the requested reservation, it classifies the packet and marks it with the available DSCP, which can approximately assure the requested QoS.
- The out-of profile traffic is stored in a buffer and shaped to be in conformance with the requested traffic profile.

Mapping of IS to DS (contd.)

- Packets are forwarded in the DS domain according to the DSCP value and the PHB group.
- The forwarding treatment is basically concerned with the queue management policy and the priority of bandwidth allocation; these ensure the required minimum queuing delay, low jitter and maximum throughput.
- Depending on the implementations of the PHB's inside the network, queue management could be RED, WRED, PQ, WFQ.

IS-DS Simulation Configuration



Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

Interoperability with Aeronautical Telecommunications Networks (ATN)

Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

Overview of ATN

- Aeronautical Telecommunications Network.
- Supporting data link based ATC application & AOC.
- Integrating Air/Ground & Ground/Ground data communications network into a global internet serving ATC & AOC.
- Introducing a new paradigm of ATC based on data link rather than voice communications.
- Operating in a different environment with different data communication service provider.
- Supporting the interconnection of Ess & Iss using a variety of subnetwork types.

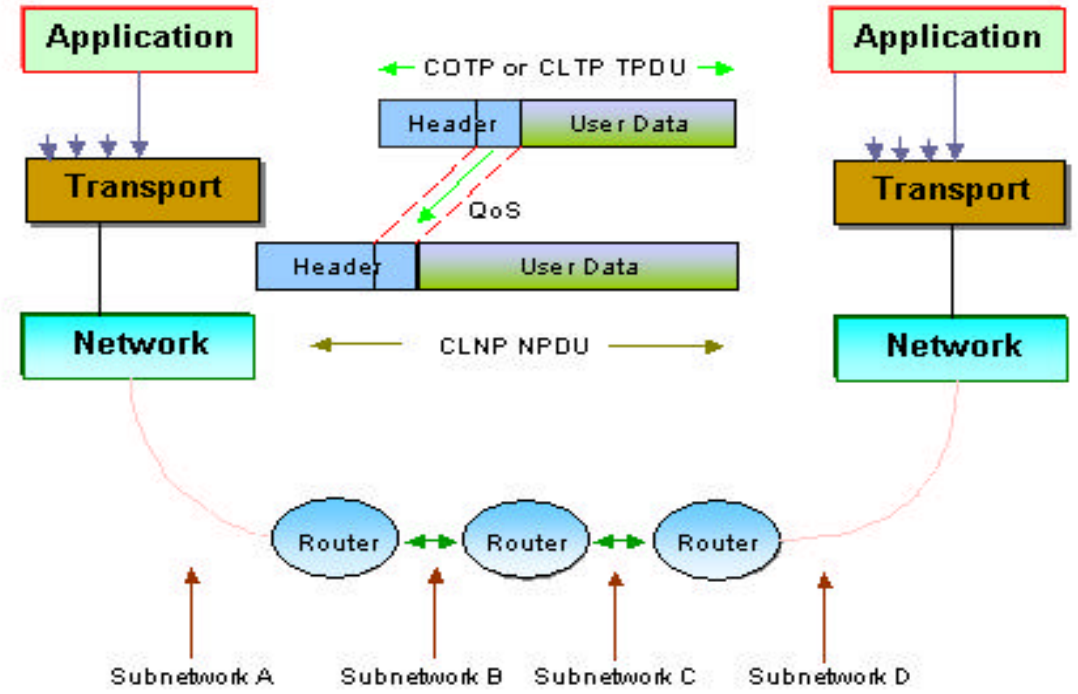
Purpose of ATN

- Using the existing infrastructure.
- High availability.
- Mobile Communications.
- Prioritized end-to-end resource management.
- Scalability.
- Policy based routing.
- Future proofing

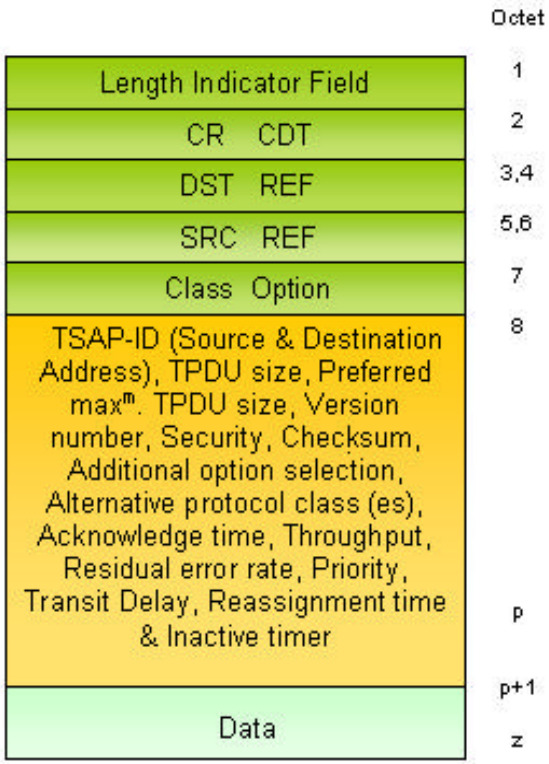
QoS of ATN

- Priority
- Transit Delay
- Error Probability
- Cost
- Security
- Reliability

Model of Transport Layer



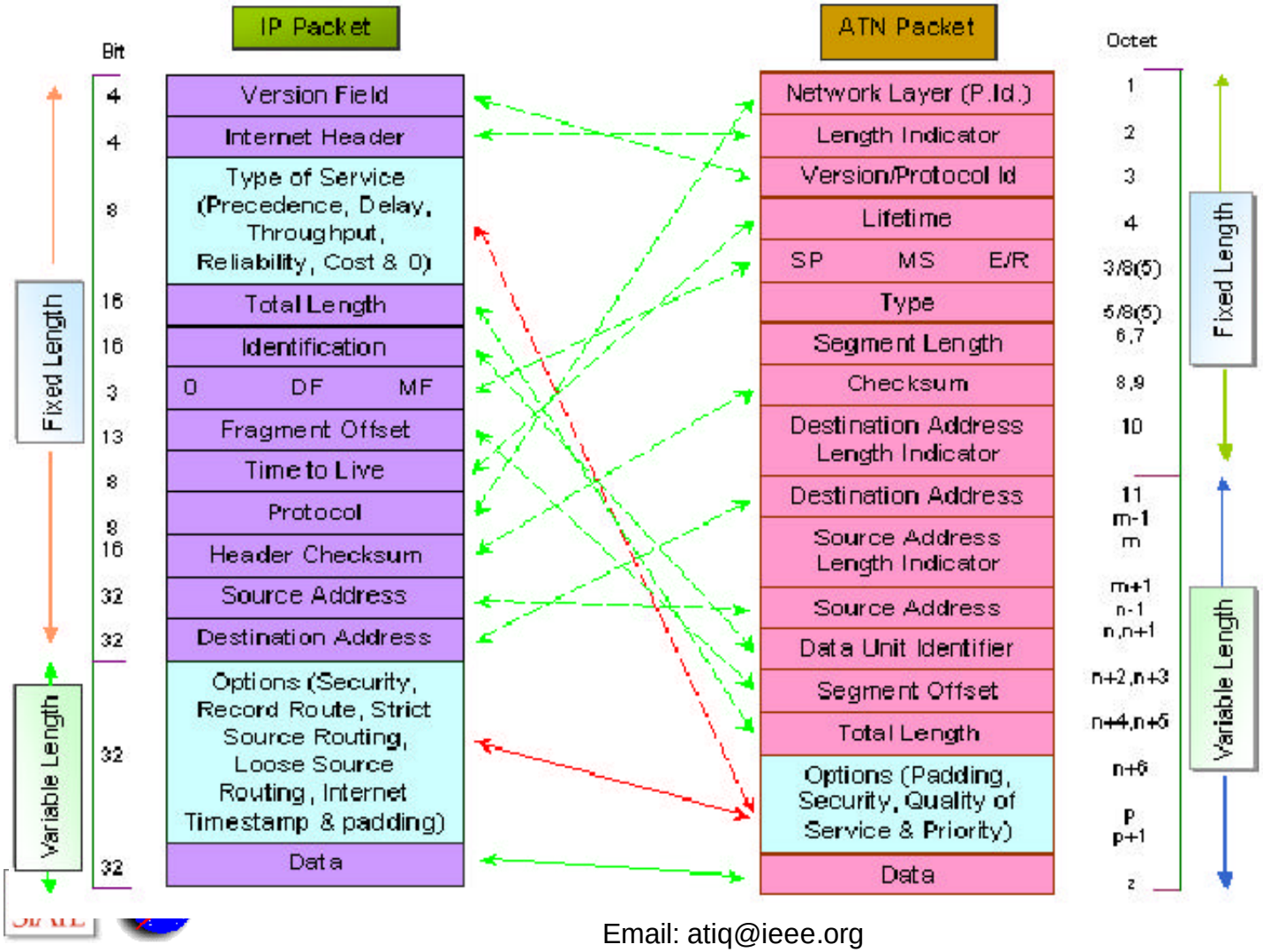
Structure of TPDU



Variable Fields of TPDU header

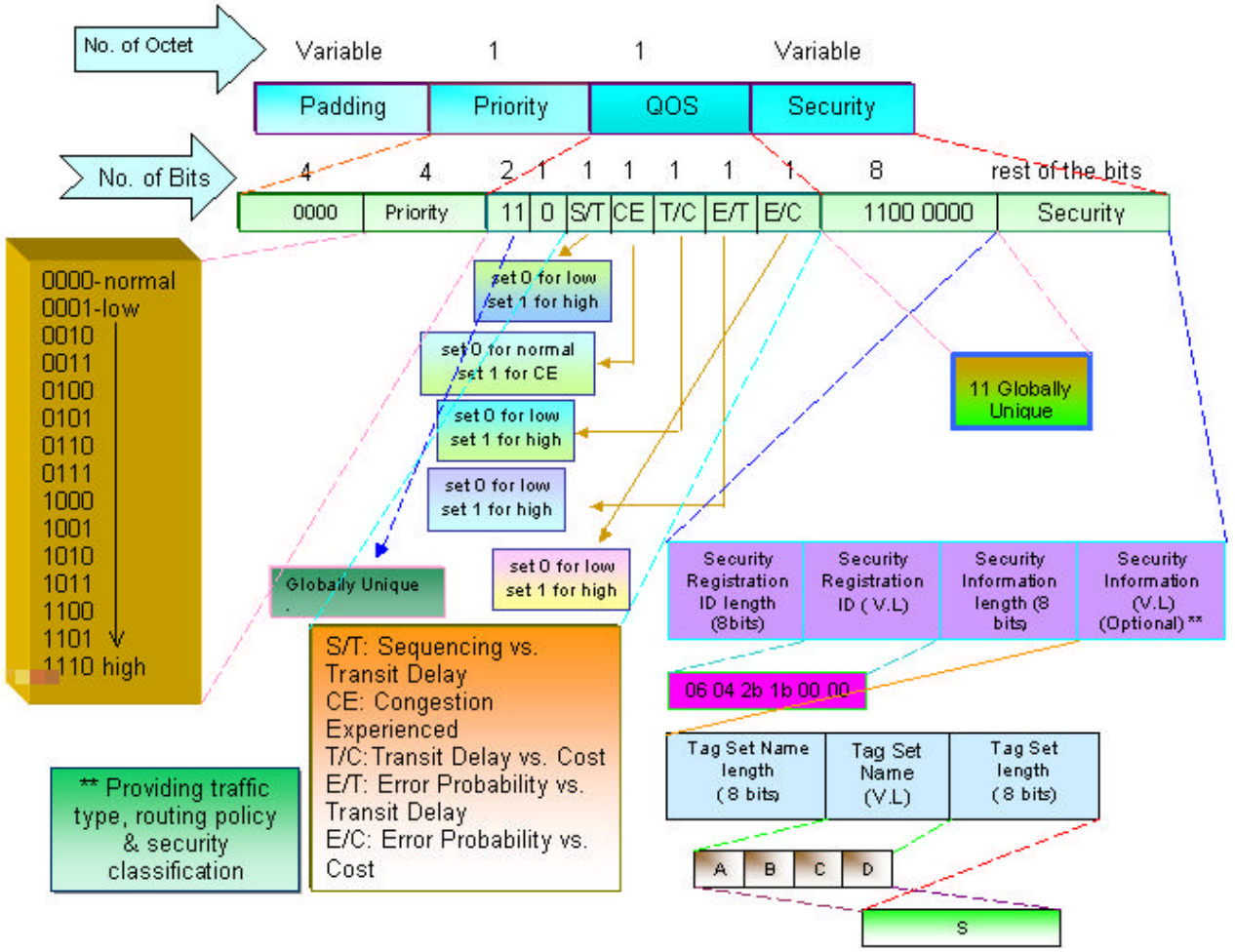
	No. of Octets
TSAP-ID (Source & Destination Address)	Variable
TPDU size	1
Preferred max^{m}. TPDU size	up to 4
Version number	1
Security	variable
Checksum	
Additional option selection	1
Alternative protocol class(es)	variable
Acknowledgement time	2
Throughput	12 Or 24
Residual error rate	3
Priority	2
Transit Delay	8
Reassignment time	2
Inactivity timer	4
Data	variable

Comparison of ATN & IP Packets



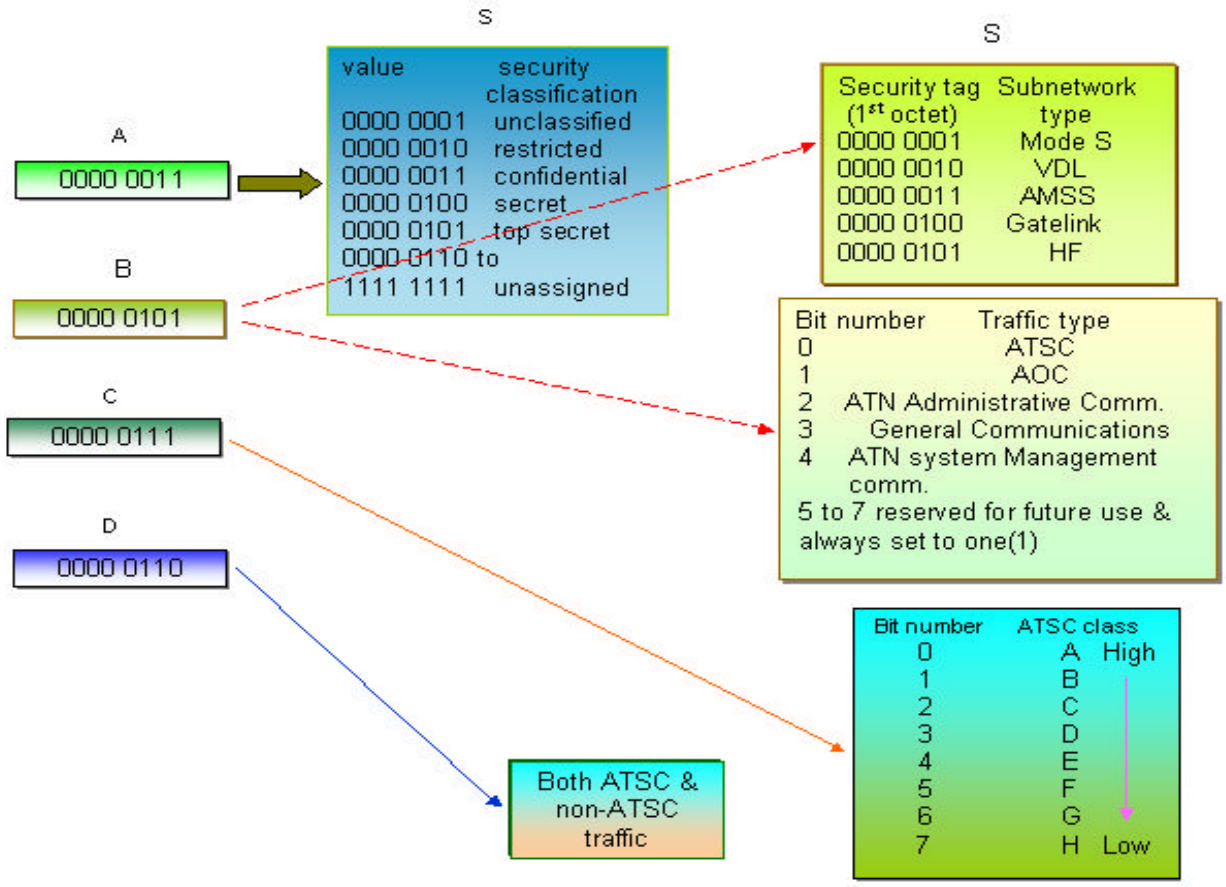
Email: atiq@ieee.org

Options Field of ATN Packet



Mohammed Atiquzzaman, University of Dayton,
Email: atiq@ieee.org

Options Field of ATN (contd.)



TPDU & NPDU Priority Translation

Message Catagories	Transport layer Priority	Network layer Priority
Network/System Management	0	14
Distress Communications	1	13
Urgent Communications	2	12
High priority Flight safety Message	3	11
Normal priority Flight safety Message	4	10
Meteorological Communications	5	9
Flight Regularity Communications	6	8
Aeronautical Information Service Message	7	7
Network/System Administration	8	6
Aeronautical Administrative Messages	9	5
<unassigned>	10	4
Urgent Priority Administration & U.N. Charter Communications	11	3
High Priority Administrative & State/Government Communications	12	2
Normal Priority Administrative	13	1
Low Priority Administrative	14	0

Priorities above the bold line are for the communications related to safety & regularity of flight

Conclusions

- Tasks are progressing well and as planned.
- Modeling of Prioritized EPD has been completed.
- OPNET simulation of Prioritized EPD to be continued.
- ns simulation of IS over DS to be continued.
- ATN over DS mapping to be started.