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"All About DQSA"

(Distributed Queue Switch Architecture)

A Remarkable Technology That Allows a Shared-Medium to Satisfy all Communications Requirements

A Tutorial

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Sharing a Channel Requires a MAC (Medium Access Control)

- The MAC on a telephone party line consisted either of good manners or just hollering louder.
- Communications between computers is subject to same economics:
  - Direct connections often underutilized
  - A plus - machines, unlike humans, can increase transmission rate.
- Hollering was no longer a solution.
- How did computer communications develop?
- Introduction of Aloha at U of Hawaii in the late 60s started search for ideal MAC.

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The Results!

- Deterministic (Collision Free) MACs:
  - TDM and FDM, Polling, Token Bus, Token Ring, bit reservation, various ring methods.
- Non-Deterministics MACs (Contention-Based):
  - ALOHA Family: Aloha, Slotted Aloha, CSMA.
- Limited Contention Protocols: CSMA/CA, Tree Protocols, Reservation protocols.

Some MACs Became Standards

- IEEE 802.3 CSMA/CD (Ethernet®): Contention.
- IEEE 802.4 Token Bus: Deterministic
- IEEE 802.5 Token Ring: Deterministic
- IEEE 802.9 Voice/Data: Split between contention and deterministic.
- IEEE 802.11 CSMA/CA: Limited contention.
- IEEE 802.12 VG AnyLAN: Deterministic.

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None Are Satisfactory

- Proliferation of IEEE 802 MACs after 802.3 (Ethernet) indicates dissatisfaction with Ethernet but it still dominates.
- But Ethernet has serious limitations:
  – Utilization restricted to 20% - 30% range.
  – Distance limited, 2 Km at 10 Mbps.
  – Does not support even rudimentary QoS.

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Only Two Physical Environments are Utilized

- Shared-Medium: Used in LANs, satellite and wireless systems.
  - Ethernet / IEEE 802.3 (CSMA / CD) dominates.
  - Wireless systems use CSMA variations.
  - Satellite systems use Aloha reservation methods.
- Switches / routers use by all other data communications.
- Phone system uses a switched environment in the form of STM (synchronous transfer method).

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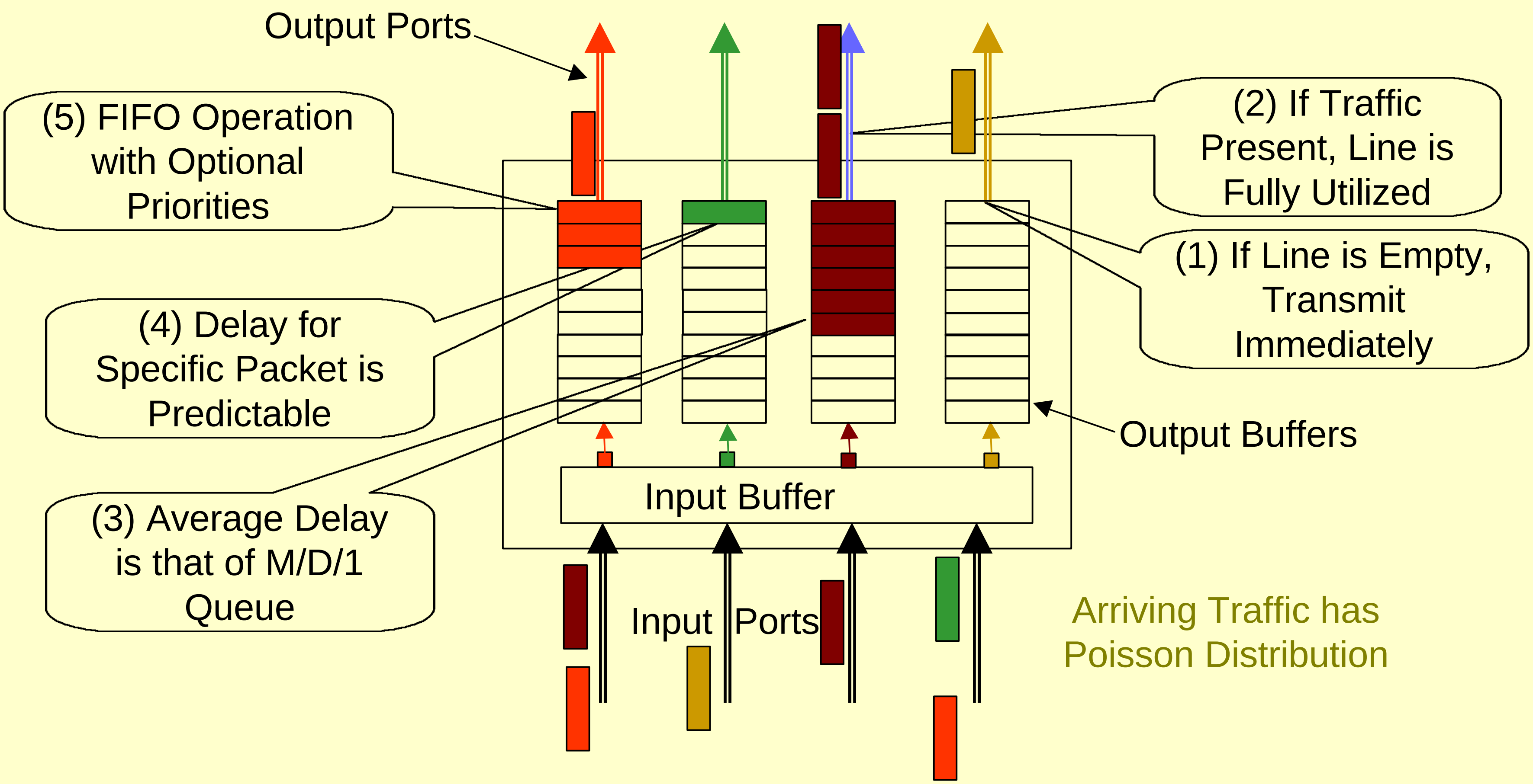
Switched Networks use Variety of Protocols

- IP, ATM, Frame Relay, X.25 on WANs.
- Switches used in Ethernet LANs to overcome distance restrictions.
- Congestion is still a problem.
- Solution, as with Ethernet, is over-engineering -- limit the offered traffic to levels well below the theoretical capacity of the system.

Features of a Packet Switch are Desirable in a Network



Arriving Traffic has Poisson Distribution

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What Features Should a MAC Provide?

1. Immediate Access.*
2. Bus Fully Utilized.
3. Average Delay that of M/D/1 Queue.
4. Delay is Predictable.
5. FIFO with Optional Priorities.

1 - 5 similar to Packet Switch. Also:

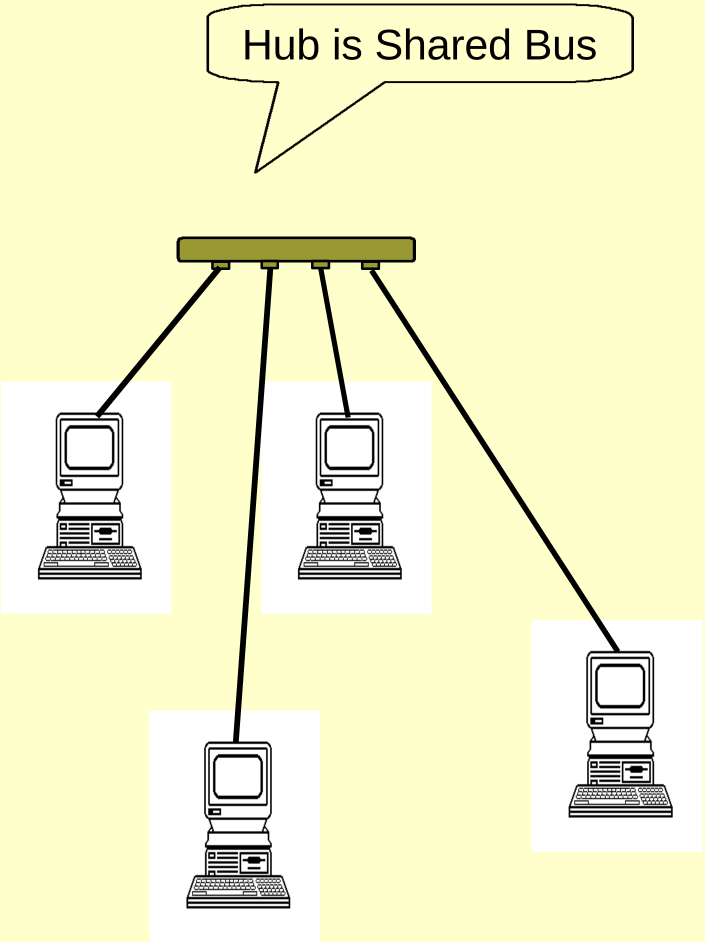
6: Distributed Control - No Master Station.*

7. QoS - Provide Guaranteed Bandwidth.

8. Topology Independent.*

9. Idle Nodes do not use Resources*.

10. Serves geographic area of any size.



* Only *1, 6, 8 and 9 supported by Ethernet.*

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DQSA Satisfies or Comes Close on All Features

- Distributed Queue Switch Architecture utilizes efficient, distant insensitive DQRAP and variations to support LANs, WANs, and STM in shared medium.
- On a single shared medium DQSA supports synchronous QOS intermixed with random access traffic over any distance. No congestion since queueing occurs at the edge of the net.
- Now, how it all came about.

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The Origin of DQSA

- In the late 1980s both Crocodile Dundee and DQDB arrive from Australia. DQDB breaks the Aloha / CSMA barrier.
- DQDB (Distributed Queue Dual Bus) is a MAC that possesses many of the ideal features but not #8.
- In DQDB ready stations each transmit a single bit upstream for each desired slot; upstream stations queue these requests letting one empty slot go by for each request.
- DQDB was basis for IEEE 802.6 MAN (Metropolitan Area Networks) standard.

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DQDB Has More Ideal Features Than Other MACs: Why Isn't It a Winner?

- Most applications use tree-and-branch, star, or passive bus topologies.
- DQDB dual bus topology requirement is the major weakness.
- Insertion of data in bus via active elements increases complexity.
- DQDB penetration of market is almost nil.

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Inspiration at IIT

- DQDB triggered search at IIT for MAC that possessed ideal features but operated on other topologies.
- On the dual bus of DQDB, single-bit requests are sent to upstream stations without danger of collision.
- On a tree-and-branch topology, single-bit requests (usually separate transmissions in as short a slot as feasible) can collide at a junction point with requests transmitted by stations on other branches. This was the problem.
- The problem was solved with DQRAP, the first member of the DQSA family.

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How Does DQRAP Do It?

- DQRAP utilizes, in addition to a data slot, three control minislots (CMS) that are used to (1) reserve a data slot, and (2) resolve contention.

- The use of minislots has been proposed many times but all previous efforts ended with the statement ". . . and with an infinite number of control minislots we achieve a throughput of 1."
- Stack algorithms achieve throughput of greater than 40% using single slots. Thus use of two CMS should provide 80% throughput and three CMS should provide 120%. Three CMS and two queues enable DQRAP to achieve 100% utilization of the dataslots.
- DQRAP actually utilizes features of existing protocols.

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DQRAP Pulls Together Features of Many MACs

- **Aloha/CSMA**: Immediate access.
- **Control Minislots**: Previous MACs using CMS required infinite number of CMS to achieve throughput of one, DQRAP needs but three.
- **DQDB**: Reservation of single slots by transmitting single signal; network status maintained by individual stations.
- **Stack Protocols**: Block new arrivals while resolving current contention.
- Next slide compares DQRAP with the ideal, note the reasonable delay at 0.95 traffic.

DQRAP Delay Compared with Ideal

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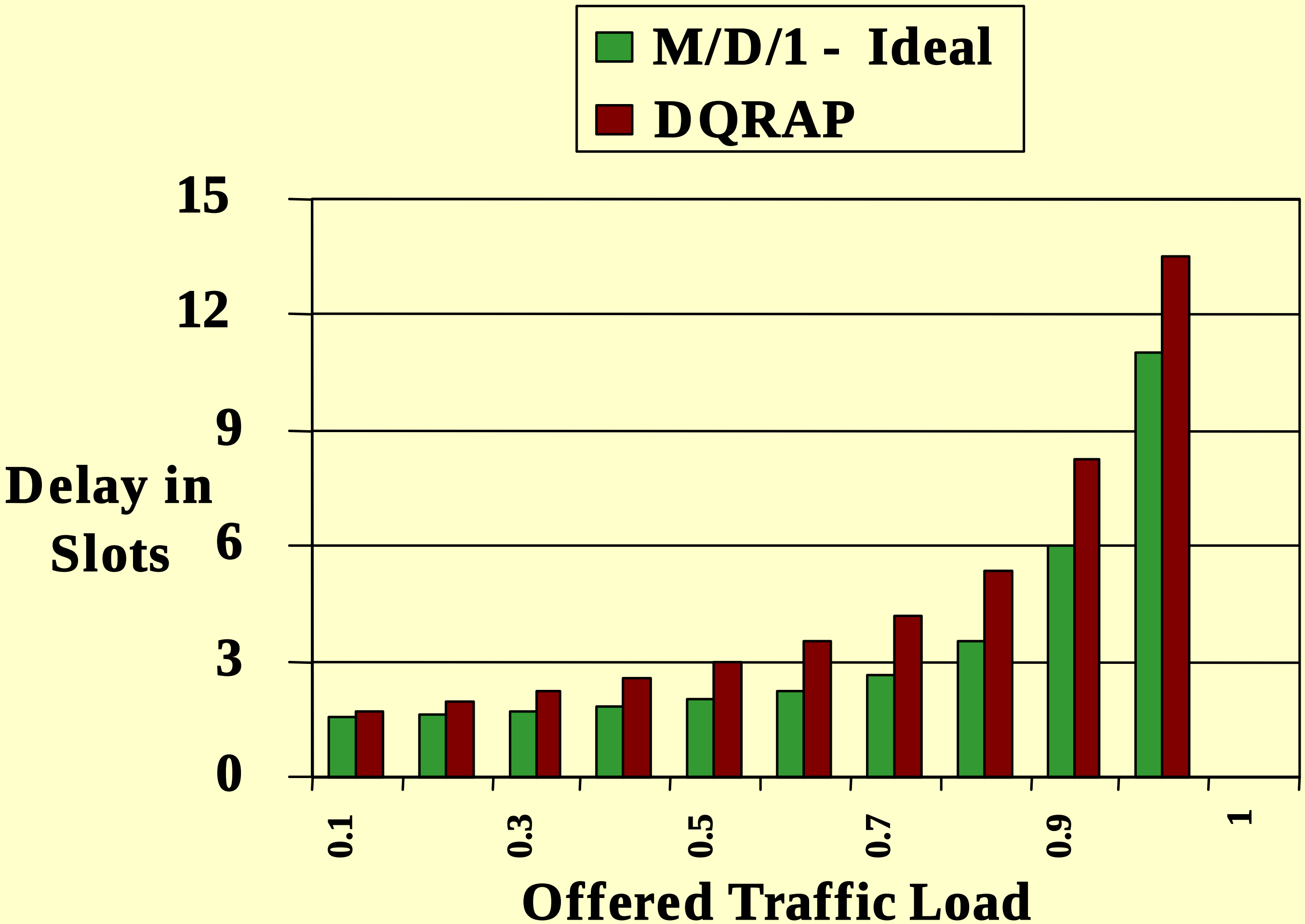

Basics of DQRAP

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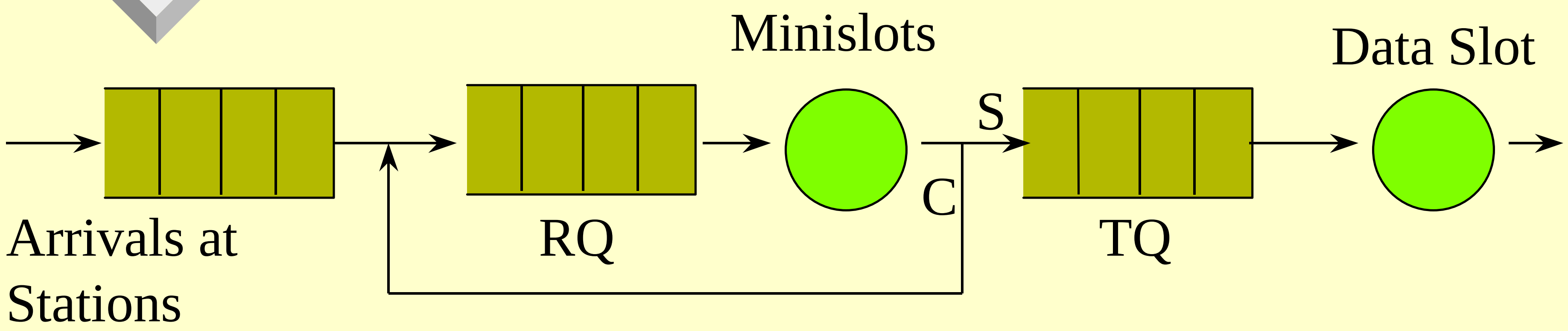
- ❖ Three sets of rules:
  - – DTR - Who can transmit data and when.
  - – RTR - Who can transmit requests and when.
  - – QDR - How does feedback affect queues?
- ❖ Three CMS to make requests, each CMS reserves one dataslot.

- ❖ Two Global Queues:
  - – TQ - Stations waiting to access data slots.
  - – RQ - Groups collided in a CMS.

Analytical Model of DQRAP



- TQ > 0 & RQ = 0: Stations transmit in minislot to make reservation.
- RQ > 0: New arrivals blocked while collided stations use minislots to resolve contention. But packets already in TQ transmit when at head of queue.
- TQ=RQ=0: Stations transmit in minislot, dataslot.

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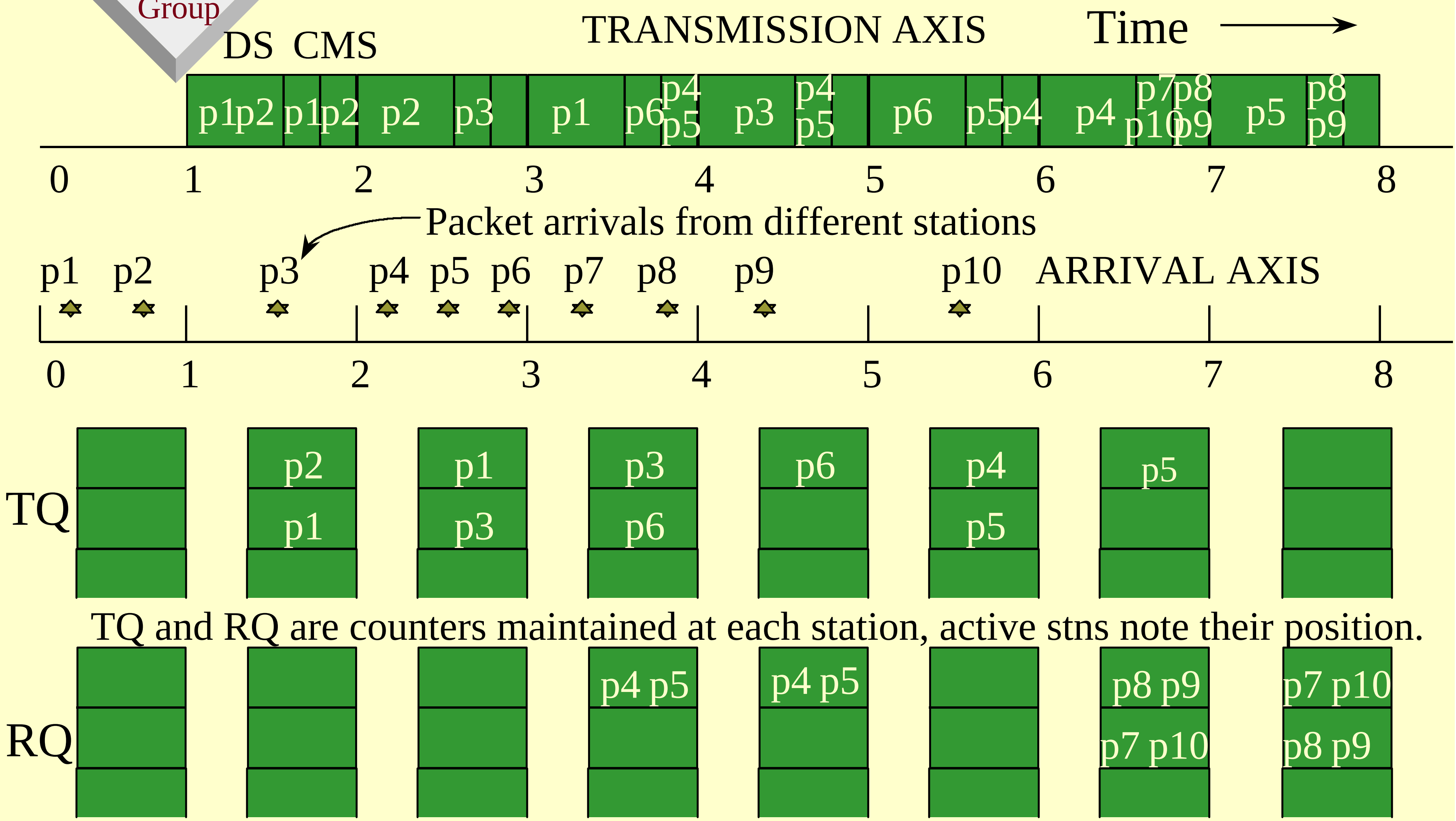
DQRAP Example - 2 Minislots



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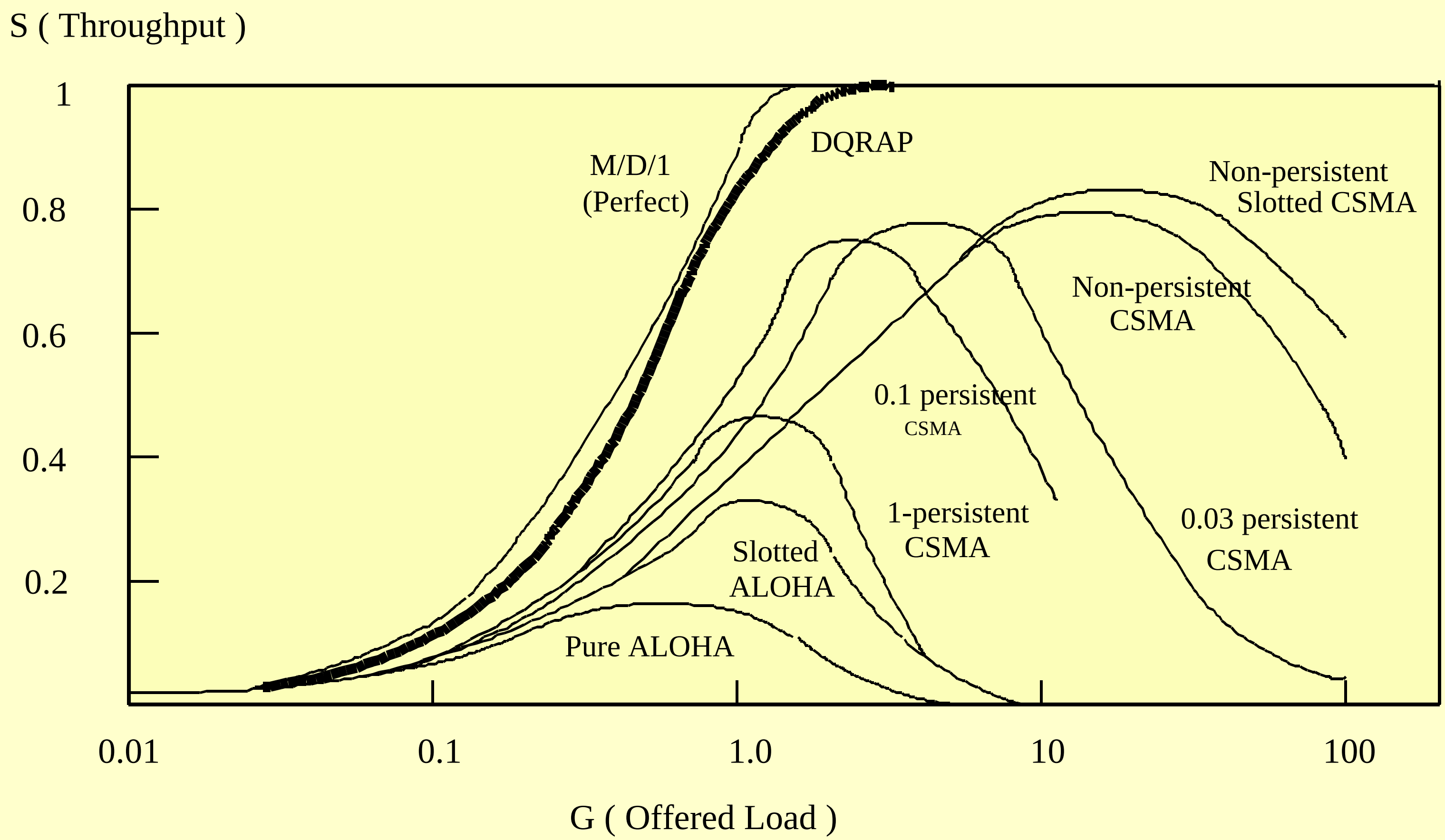
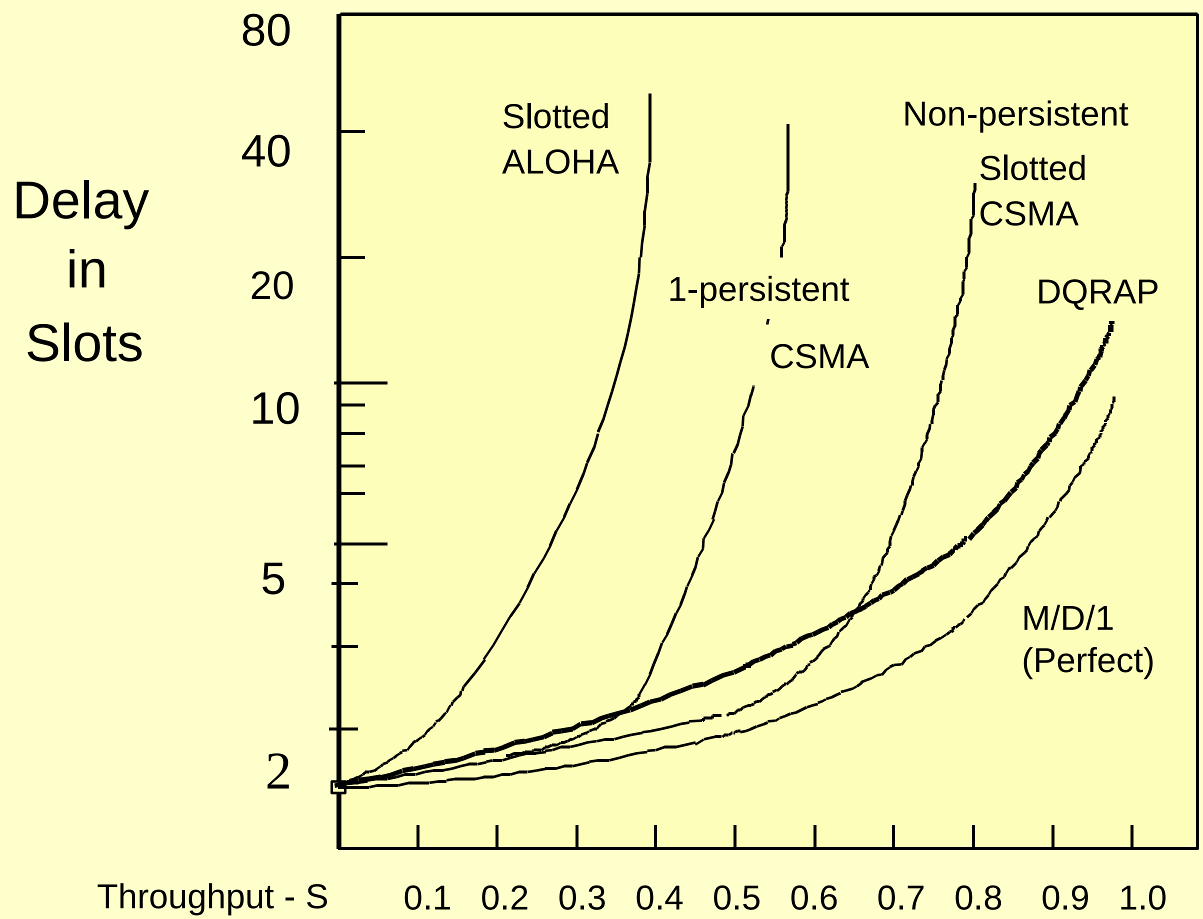
Highlights of Example

- p1, p2 transmit in both CMS and dataslot since TQ = RQ = 0, p2 goes to head of TQ.
- p3 xmits in CMS since TQ > 0, joins TQ.
- p4, p5 collide, RQ incremented. New traffic blocked while p4,p5 resolve.
- While p4,p5 resolve in CMS, data transmission continues from TQ.
- After p4,p5 resolve, waiting traffic p7,p8,p9 and p10 transmit in CMS, go to RQ.

COMPARISON OF THROUGHPUT

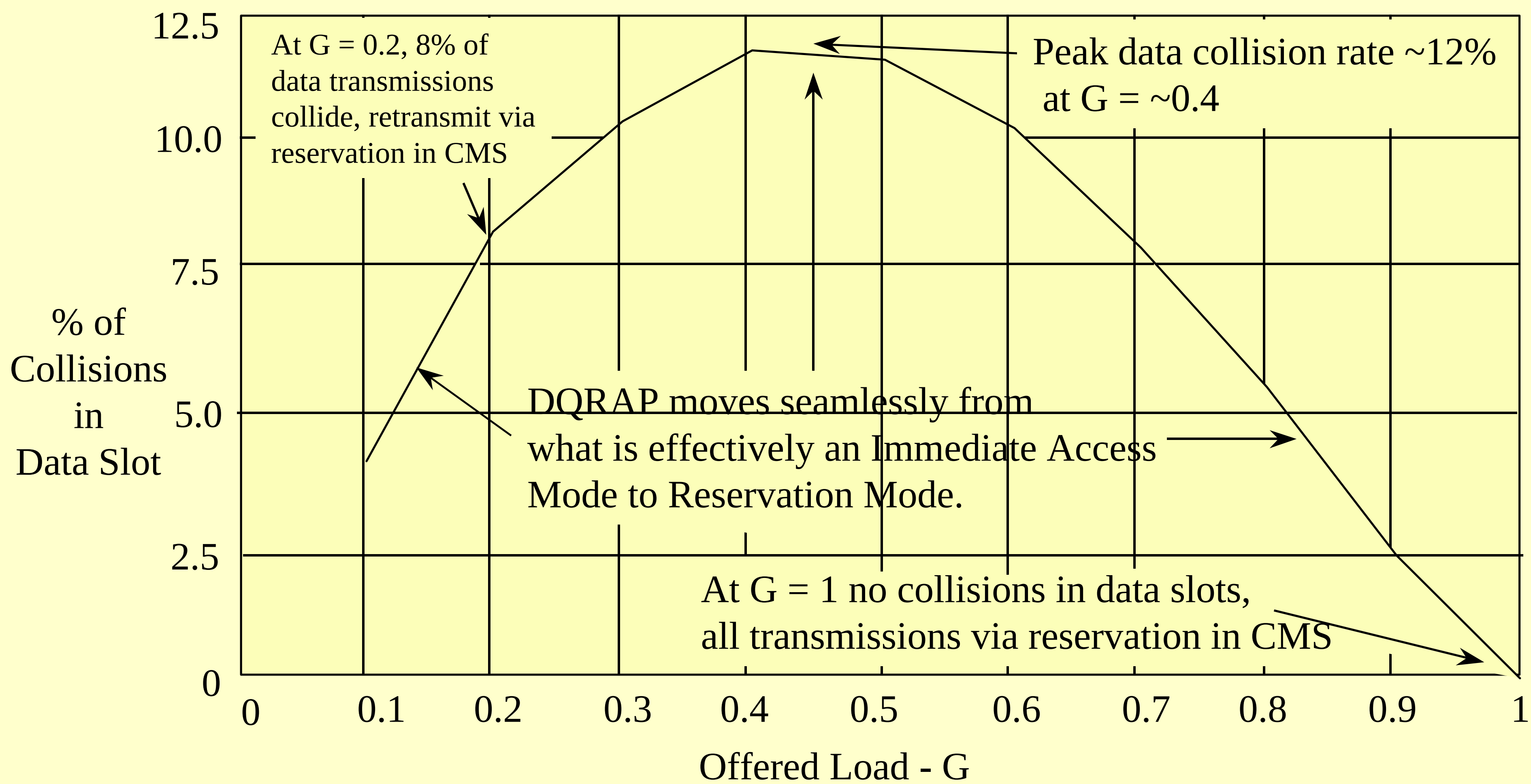


Comparison of Delay



How Often Does Data Collide?

(Collisions only occur when TQ == 0, no station waiting, using otherwise empty slot thus throughput not affected.)



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What Have we Shown?

- With respect to throughput and delay DQRAP is superior to all other MACs.
- Let us look at the remarkable enhancements that make up the DQSA family thus providing one-stop shopping for all communications needs.

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PDQRAP (Priority DQRAP) Performance

(Mixture of High and Normal Priority Traffic)

Total Load 90%		Delay in Slots		Average
High	Normal	High	Normal	Delay
0.10	0.80	4.29	9.19	8.64
0.20	0.70	4.36	9.74	8.54
0.30	0.60	4.4	10.59	8.53
0.40	0.50	4.52	11.77	8.55
0.50	0.40	4.66	13.28	8.49
0.60	0.30	4.78	15.58	8.38
0.70	0.20	5.19	19.4	8.35
0.80	0.10	5.81	28.37	8.41

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XDQRAP(Extended DQRAP) A Remarkable Variation

- In DQRAP, each transmission into a CMS is a request to reserve a single dataslot.
- In XDQRAP each transmission in a CMS is a request to reserve a multiple number of dataslots.
- Variable length packets are segmented and the segments (cells) transmitted with no further encapsulation.
- Big Plus! XDQRAP requires but two minislots to achieve 100% utilization of dataslots.
- XDQRAP is basis for distributed Ethernet, IP, and Frame Relay switches.

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DQLAN - Distributed Queue LAN

- DQRAP and XDQRAP utilize fixed-length slots requiring segmentation.
- DQLAN supports variable length frames with no segmentation, but can only be implemented when “a” <= 0.5 (ala Ethernet).
- Topology similar to 10BaseT, i.e., star topology.
- Hub similar to Ethernet hub is used.

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What About Distance?

- Use of interleaving, sometimes called pipelining, enables DQRAP and XDQRAP to be deployed over any distance.
- Makes feasible WANs using hub and spoke topology that permits hundreds of stations to be directly connected to a T1 or DS3 spoke.
- A DQSA T1/DS3 WAN is “routerless”.

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How Robust is DQRAP?

- Arrival of multiplicity N is resolved in less than N dataslots ensuring 100% throughput.
- Errors in reading CMS and retransmission in CMS do not affect data transmission unless arrival of multiplicity N not resolved in N dataslots.
- *DQRAP can sustain up to 10% error rate in cms before data throughput drops below 1.*

Why DQRAP is so Robust.

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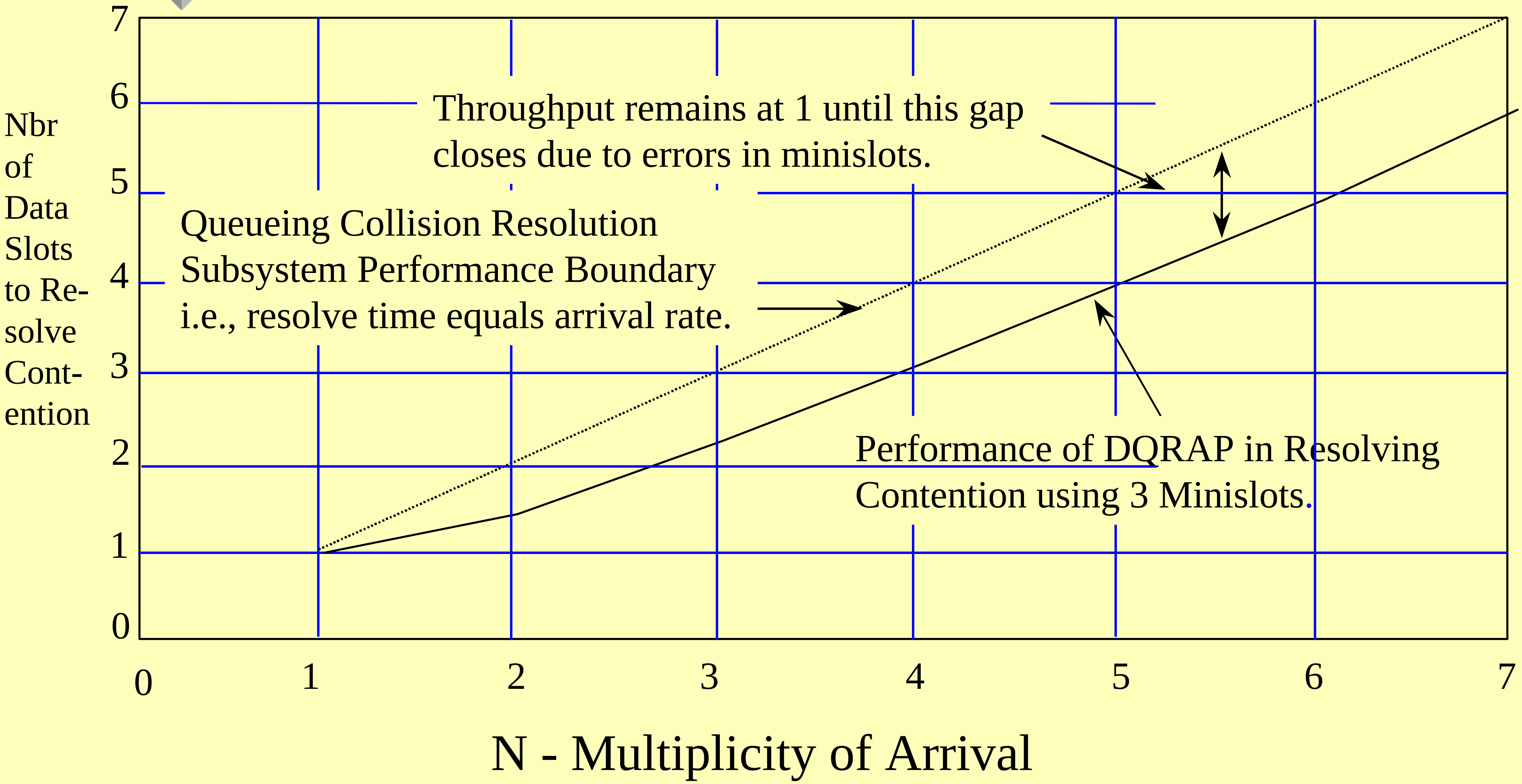

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Advantages of DQSA

- Physical access to bus is same as Ethernet:
  - write operation equivalent of simple “or”.
  - read operation is equivalent of “copy”.
  - data rate limited only by ability to read from and write to the medium.
- Implemented over arbitrary distances.
- Suitable for rf, baseband, fiber and digital media.

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How About QoS?

- DQSA supports QoS (Quality of Service) using 3 classes as defined in Microsoft NDIS:
  1 Best Effort: Equivalent to conventional transmissions under DQSA where average delay is 8.25 slots at offered traffic of 90%.
  2 Controlled Load: Delay equivalent to lightly loaded network. PDQ provides ~4 slot delay for 20% high priority in 90% total traffic.
  3 Guaranteed Service: DQSA mixes equivalent of TDM-like channels with random access.

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New Thinking in Communications

- Conventional wisdom is that shared-medium networks are confined to LANs (except for satellite and wireless), everything else uses packet/cell switching.
- DQSA permits a network to be organized as a shared-medium channel operating as a distributed switch.
- In practical terms this means that hub-and-spoke, used with people (airlines), parcels (Fedex), can be used to move packets.
- DQSA hub can be switched, i.e., switch packets to specific spoke, or non-switched, i.e., copy packet to all spokes.

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Summary

- Virtually all communication requirements can be satisfied on a shared-medium using the random access / reservation features of DQSA.
- The DQSA Research Group is continuing research into Cascaded Distributed Queue (CDQ) networks. CDQ “cascades” DQSA networks such that locality is supported, i.e., packets do not have to travel to a central hub. CDQ holds promise of being the ideal backbone for the Internet.
- Contact Professor Graham Campbell for further information.