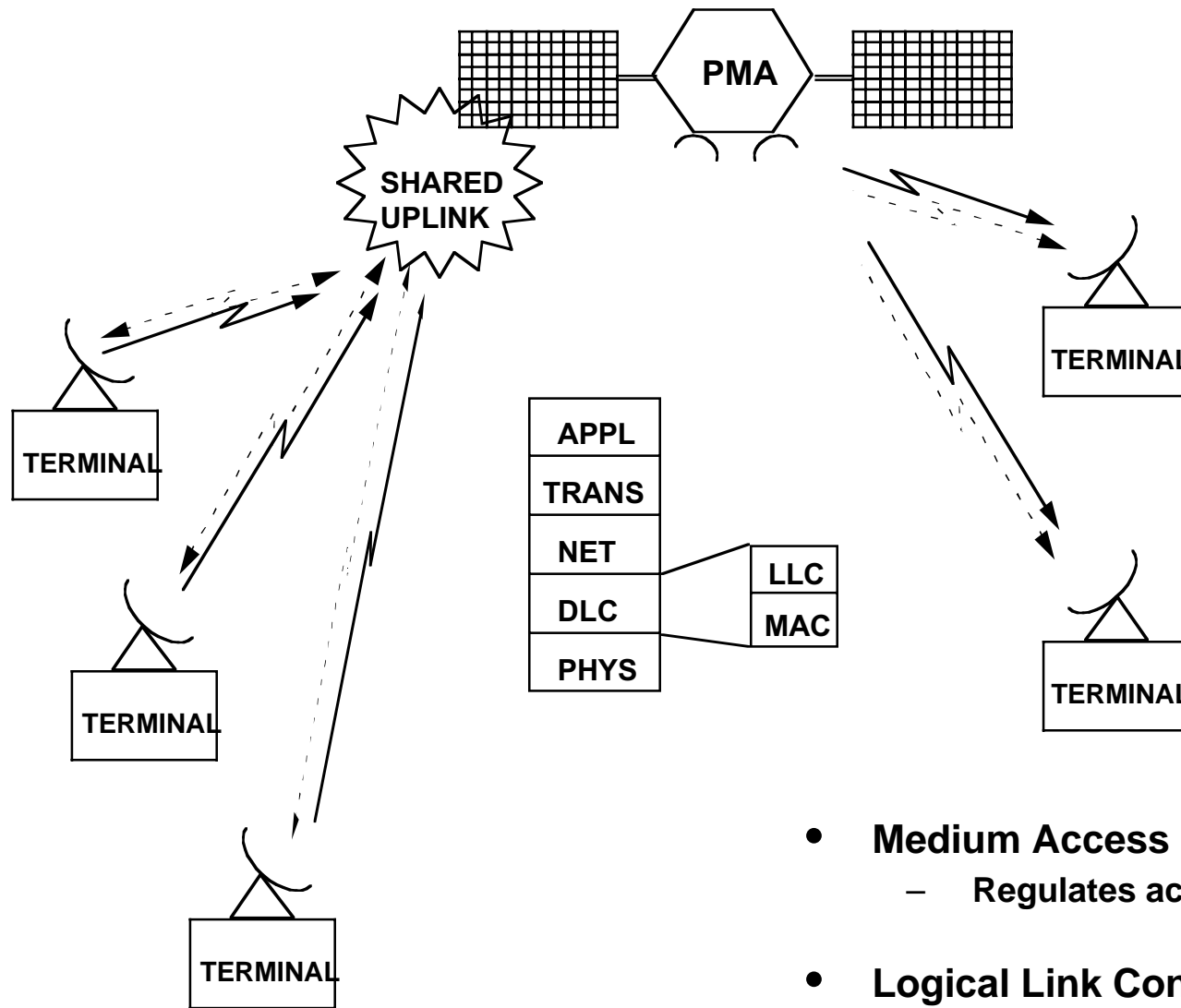# Packet multiple access and the Aloha protocol

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Packet Multiple Access

APPL

TRANS

NET

DLC

PHYS

LLC

MAC

- **Medium Access Control (MAC)**
  - Regulates access to channel

- **Logical Link Control (LLC)**
  - All other DLC functions

Examples of Multiple Access Channels

- **Local area networks (LANs)**

- **Satellite channels**

- **Wireless radio**

- **Characteristics of Multiple Access Channel**
  - **Shared Transmission Medium**
    - A receiver can hear multiple transmitters
    - A transmitter can be heard by multiple receivers

  - **The major problem with multiple access is allocating the channel between the users**
    - Nodes do not know when other nodes have data to send
    - Need to coordinate transmissions
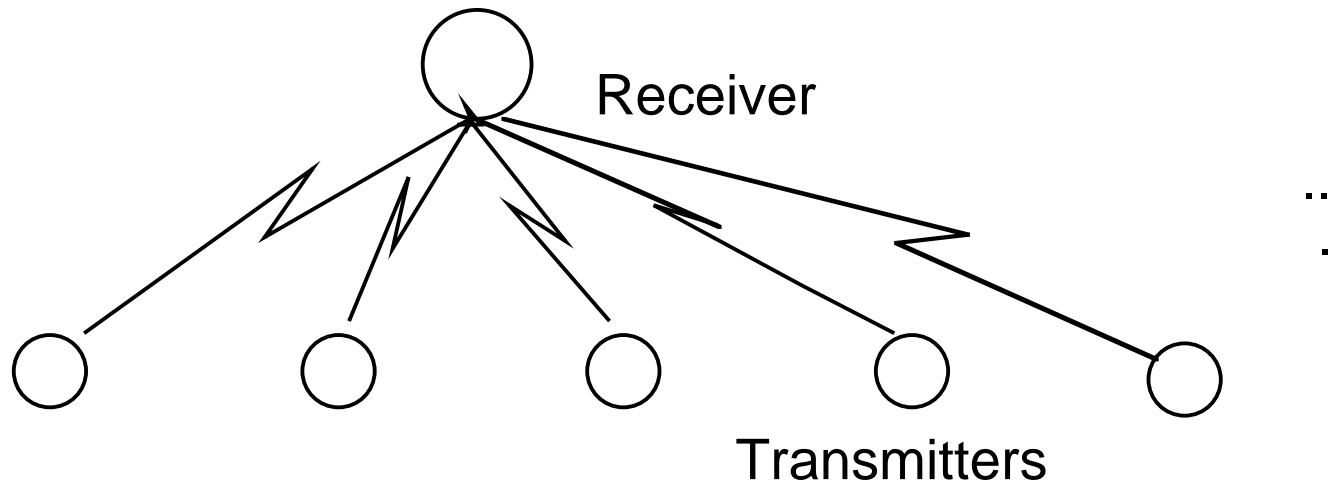
Approaches to Multiple Access

- **Fixed Assignment (TDMA, FDMA, CDMA)**
  - **Each node is allocated a fixed fraction of bandwidth**
  - **Equivalent to circuit switching**
  - **very inefficient for low duty factor traffic**

- **Packet multiple access**

  - **Polling**

  - **Reservations and Scheduling**

  - **Random Access**

Aloha

Single receiver, many transmitters

Receiver

Transmitters

... .

E.g., Satellite system, wireless

Slotted Aloha

- **Time is divided into "slots" of one packet duration**
  - **E.g., fixed size packets**
- **When a node has a packet to send, it waits until the start of the next slot to send it**
  - **Requires synchronization**
- **If no other nodes attempt transmission during that slot, the transmission is successful**
  - **Otherwise "collision"**
  - **Collided packet are retransmitted after a random delay**

1	2	3	4	5
Success	Idle	Collision	Idle	Success
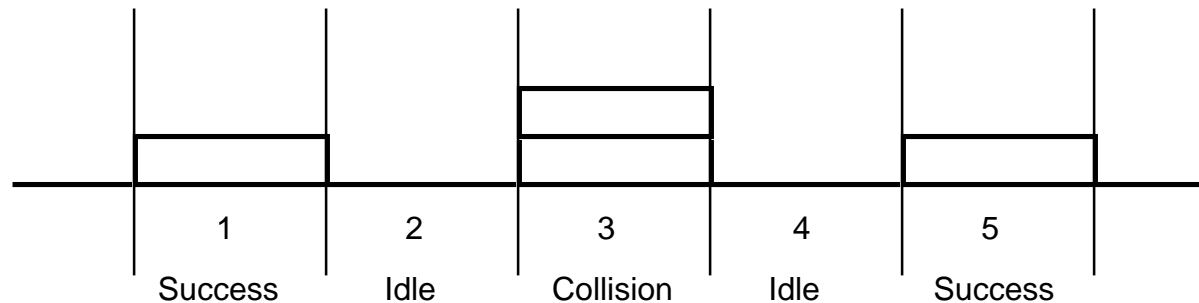
Slotted Aloha Assumptions

- **Poisson <u>external</u> arrivals**

- **No capture**
  - Packets involved in a collision are lost
  - Capture models are also possible

- **Immediate feedback**
  - Idle (0) , Success (1), Collision (e)

- **If a new packet arrives during a slot, transmit in next slot**

- **If a transmission has a collision, it becomes backlogged and retransmitted after a random delay**
 - Let n be the number of backlogged nodes

slotted aloha

- **Let g be the attempt rate (the expected number of packets transmitted in a slot)**

  - **The number of attempted packets per slot is approximately a Poisson random variable of mean $g = \lambda + n \ast q_r$**

    - q_r = probability that a backlogged packet is retransmitted in a slot
    - n = number of backlogged packets

  - **P (m attempts) = $g^m e^{-g}/m!$**
  - **P (idle) = probability of no attempts in a slot = e^{-g}**
  - **p (success) = probability of one attempt in a slot = ge^{-g}**
  - **P (collision) = P (two or more attempts) = 1 - P(idle) - P(success)**

Throughput of Slotted Aloha

- **The throughput is the fraction of slots that contain a successful transmission = P(success) = ge^{-g}**

  - When system is stable throughput must also equal the external arrival rate (λ)

e^{-1}

ge^{-g}

Departure rate

1

g
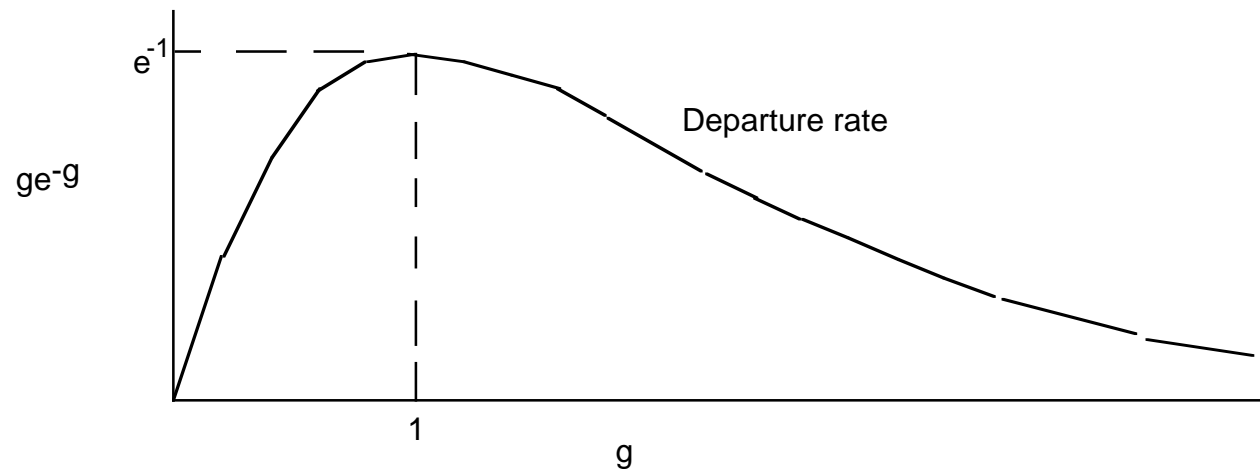
  - **What value of g maximizes throughput?**

$$\frac{d}{dg(n)} ge^{-g} = e^{-g} - ge^{-g} = 0$$

$$\Rightarrow g = 1$$

  - **g < 1 => too many idle slots**
  - **g > 1 => too many collisions**

$$\Rightarrow P(success) = ge^{-g} = 1/e \approx 0.36$$

  - **If g can be kept close to 1, an external arrival rate of 1/e packets per slot can be sustained**
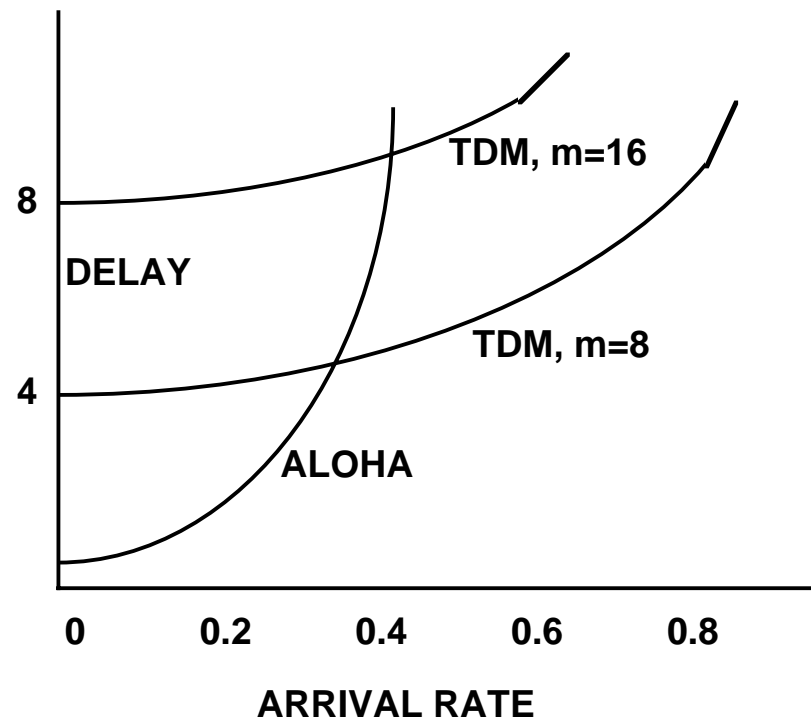
Instability of slotted aloha

- **if backlog increases beyond unstable point (bad luck) then it tends to increase without limit and the departure rate drops to 0**
  - **Aloha is inherently unstable and needs algorithm to keep it stable**

- **Drift in state n, D(n) is the expected change in backlog over one time slot**
  - $D(n) = \lambda - P(success) = \lambda - g(n)e^{-g(n)}$
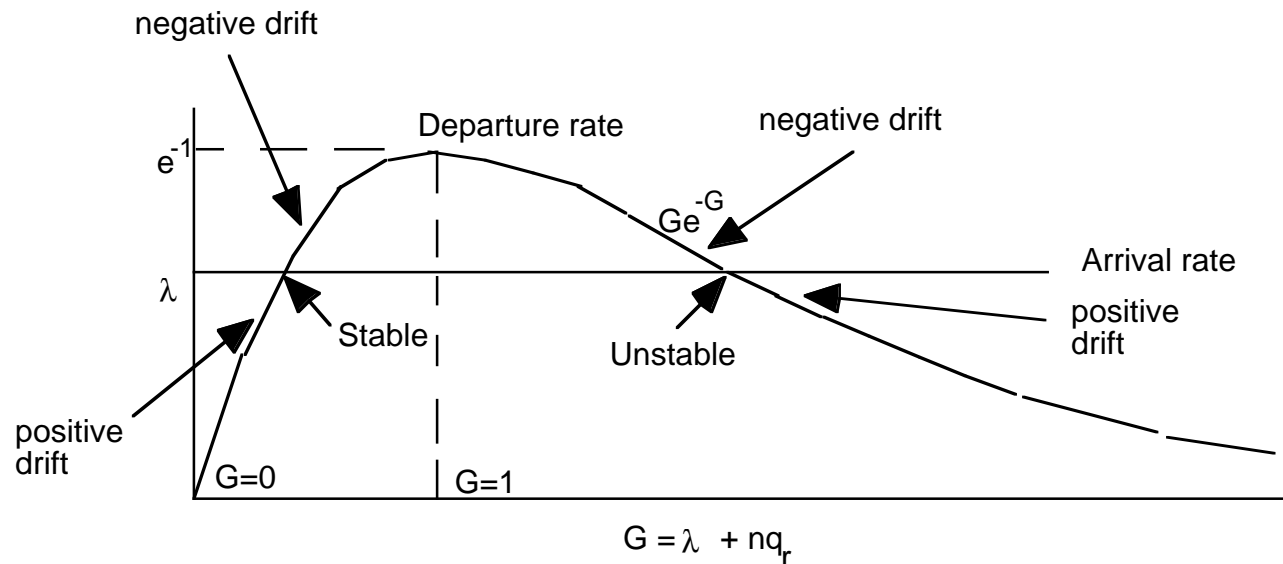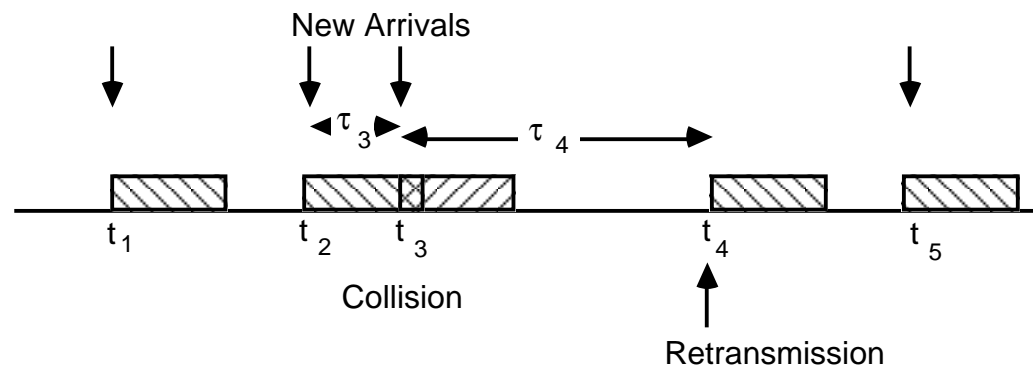
TDM vs. slotted aloha

- **Aloha achieves lower delays when arrival rates are low**
- **TDM results in very large delays with large number of users, while Aloha is independent of the number of users**

Pure (unslotted) Aloha

- **New arrivals are transmitted immediately (no slots)**
  - **No need for synchronization**
  - **No need for fixed length packets**

- **A backlogged packet is retried after an exponentially distributed random delay with some mean 1/x**

- **The total arrival process is a time varying Poisson process of rate $g(n) = \lambda + nx$ (n = backlog, 1/x = ave. time between retransmissions)**

- **Note that an attempt suffers a collision if the previous attempt is not yet finished ($t_i - t_{i-1} < 1$) or the next attempt starts too soon ($t_{i+1} - t_i < 1$)**

New Arrivals

τ_3 τ_4

t_1 t_2 t_3 t_4 t_5

Collision

Retransmission

Throughput of Unslotted Aloha

- **An attempt is successful if the inter-attempt intervals on both sides exceed 1 (for unit duration packets)**

    - **P(success) = e^{-g} x e^{-g} = e^{-2g}**

    - **Throughput (success rate) = ge^{-2g}**

    - **Max throughput at g = 1/2, Throughput = 1/2e ~ 0.18**

    - **Stabilization issues are similar to slotted aloha**

    - **Advantages of unslotted aloha are simplicity and possibility of unequal length packets**

Splitting Algorithms

- **More efficient approach to resolving collisions**
    - **Simple feedback (0,1,e)**
    - **Basic idea: assume only two packets are involved in a collision**
        - **Suppose all other nodes remain quiet until collision is resolved, and nodes in the collision each transmit with probability 1/2 until one is successful**

        - **On the next slot after this success, the other node transmits**

        - **The expected number of slots for the first success is 2, so the expected number of slots to transmit 2 packets is 3 slots**

        - **Throughput over the 3 slots = 2/3**

    - **In practice above algorithm cannot really work**
        - **Cannot assume only two users involved in collision**
   - **Practical algorithm must allow for collisions involving unknown number of users**

Tree algorithms

- **After a collision, all new arrivals and all backlogged packets not involved in the collision wait**
- **Each colliding packet randomly joins either one of two groups (Left and Right groups)**
  - **Toss of a fair coin**
  - **Left group transmits during next slot while Right group waits**
    - If collision occurs Left group splits again (stack algorithm)
    - Right group waits until Left collision is resolved
  - **When Left group is done, right group transmits**
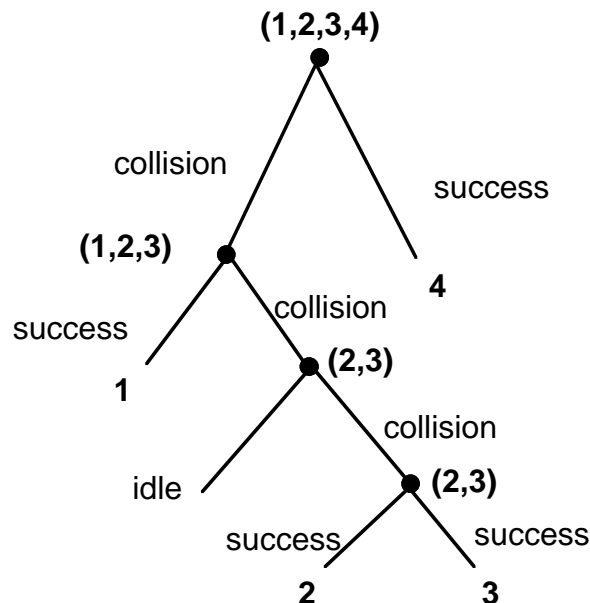
Notice that after the idle slot, collision between (2,3) was sure to happen and could have been avoided

Many variations and improvements on the original tree splitting algorithm

Throughput comparison

- **Stabilized pure aloha T = 0.184 = (1/(2e))**

- **Stabilized slotted aloha T = 0.368 = (1/e)**

- **Basic tree algorithm   T = 0.434**

- **Best known variation on tree algorithm T = 0.4878**

- **Upper bound on any collision resolution algorithm with (0,1,e) feedback T <= 0.568**

- **TDM achieves throughputs up to 1 packet per slot, but the delay increases linearly with the number of nodes**