UNIT-V

UNIT-V:
Satellite Packet Communications: Message Transmission by FDMA: M/G/1 Queue, Message Transmission by TDMA, PURE ALOHA-Satellite Packet Switching, Slotted Aloha, Packet Reservation, Tree Algorithm.

Introduction

Satellite communication refers to radio-link (microwave Line of Sight) communication using one or more radio frequency re-transmitters located at great distances from the terminal earth stations. The use of satellite in communication systems has become so habitual it is almost taken for granted. The ubiquity of direct to home (DTH) satellite dishes in cities around the world is a testimonial to this fact. These antennas are used for reception of satellite signals for television. Satellites also form an essential part of the communication system worldwide carrying a large amount of data and telephone traffic in addition to multimedia signals. The use of satellite technology for communication purposes comes with attendant important features, which are not readily available through other means of communication namely:

1. A satellite in the geosynchronous orbit effectively covers close to 120 degree sector of the earth surface, thus making beyond-LoS communication a reality, i.e. communication is possible beyond earth curvature (which sets the limit line of sight).
2. Satellite communications is not concerned with either political or geographical boundaries.
3. Satellites provide both fixed and mobile communication service, the former is called fixed satellite service (FSS), while the latter interconnects with moving object (e.g. aircraft) from a ground control station.
4. Satellites offer last-mile communication solution to remote communities that may be difficult to access otherwise.
5. Satellite communication is employed in remote sensing for prospecting natural resources as well as monitoring atmospheric conditions.
6. Three communication satellites situated at the geostationary altitude and spaced 120 degrees apart could interconnect over 90% of the earth.
7. A satellite communication network is easily expandable.

Every communications satellite in its simplest form performs the task of transmitting information from a source earth station to the satellite (this is called the uplink). This is followed by a retransmission of the received and processed information from the satellite back to the ground (this is called the downlink). The downlink may either be to a select number of ground stations or it may be broadcast to all receiving terminals in the satellite's footprint. Here, we focus on specific protocols or methods guiding access to the medium used for transmission and retransmission of packets (messages) to and from the satellites. These protocols are referred to as Medium Access Schemes. Medium Access Control (MAC) schemes are mechanisms for sharing a single link. MAC schemes are essentially multiplexing schemes. Message access on any system can be of three types:

1. Conflict-free Scheme
2. Contention (random access) Scheme
3. Reservation (controlled access) Scheme

There are also hybrid schemes between contention and reservation. This paper considers message transmission by FDMA using the M/G/1 Queue under the Conflict-free Scheme and message transmission by TDMA using Pure ALOHA, Slotted ALOHA, Tree Algorithm and Packet reservations under the Contention/Random Access Scheme.

Message Transmission by FDMA

With Frequency Division Multiple Access (FDMA) the entire available frequency channel is divided into bands and each band serves a single station. Every station is therefore equipped with a transmitter for a given frequency band, and a receiver for each band. To evaluate the performance of the FDMA protocol, we assume that the entire channel can sustain a rate of R bits/sec which is equally divided among M stations i.e. R/M bits/sec for each. The individual bands do not overlap as such there is no interference among transmitting stations. This allows for viewing the system as M mutually independent queues. Each of these queues has an individual input process governing the packet generation process for that user. If the packet length is a random variable P, then the service time afforded to every packet is the random variable $\mathcal{T} = MP/R$.

To evaluate the throughput of the individual station we note that every bit transmitted is a "good" bit and thus the individual throughput is the fraction of time the individual server is busy. The total throughput is M times the individual throughput while the average packet delay can be obtained by applying Little's result to the individual queue. In general, all parameters relating to FDMA can be obtained by applying known results of the corresponding queue discipline.

a. M/G/1 QUEUE

Consider a queuing system, in which arrivals occur according to a Poisson process with parameter and in which x is the service rendered to the customers, is distributed according to a distribution *B(t).* In such a queuing system, an outside observer sees the number of customers in the system as equal to that seen by an arriving customer, which equals that seen by a departing customer. The following holds for an M/G/1 queuing system:

$$D = x + W = x + \frac{\lambda x^2}{2(1-\lambda T)}$$

Where D = Average delay time, p = λx = Load factor, W = Queuing time.

Therefore, for an FDMA system, considering a typical user that generates packets according to a Poisson process with rate λ packets/sec and its buffering capabilities are not limited, the time required for the transmission of a packet is . Each node can therefore be viewed as an M/G/1 queue since each packet size is not constant. Thus, using the known system delay time formula for M/G/1 queuing systems we get that the expected delay of a packet is:

$$D = T + \frac{\lambda T^2}{2(1-\lambda T)}$$

And the delay is distribution is given by,

$$D^* = X^*(s)\,\frac{s(1-p)}{s-\lambda+\lambda X*(s)}$$

Where X*(s) is the laplace transform of the transmission time.

Message Transmission by TDMA

In the time division multiple access (TDMA) scheme the entire time frame is divided into time slots, pre-assigned to the different stations. Every station is allowed to transmit freely during the slot assigned to it, that is, during the assigned slot the entire system resources are devoted to that station. Techniques based on contention are suitable for traffic that is bursty in nature. Centralized control is absent in a contention-based system, as such when a node needs to transmit data, it contends for control of the transmission medium. The major advantage of contention techniques is simplicity, as they are easily implementable in individual nodes. The contention techniques are efficient under light to moderate network load, but performance rapidly degrades with increase in load level. Message transmission by TDMA can be done using the ALOHA protocol, packet reservation and tree algorithm. The ALOHA scheme was invented at the University of Hawaii for the purpose of interconnecting remote stations and data terminals to a central server over a packet radio network.

The ALOHA model vis-a-vis satellite communications uses satellite connections between earth stations. The model consists of three top-level modules: an earth station (earth segment), a central satellite station (space segment) that serves as the communications link between the earth stations and a statistics module. Towards achieving the objective of a simple design, some functions such as satellite round-trip delay, collision detection, and transmission delay are implemented on the satellite. Any collision detected during the receipt of a packet by the satellite is tagged before onward broadcast to receiving earth stations. A continuous retransmit process is initiated by the transmitting earth station until it receives the original packet back without the collision flag. At which point the packet is discarded, and the transmission of the next packet in queue commences. Suffice to note here that all packets are equal in size and both pure and slotted ALOHA operations are supported by the earth station module.

Random Access

Random Access is a widely used satellite multiple access technique where the traffic density from individual users is low. For example, VSAT terminals and satellite mobile telephones often require communication capacity infrequently.

These users can share transponder space without any central control or allocation of time or frequency, provided the average activity level is sufficiently low.

In a true random access network, a user transmits packets whenever they are available.

The packet has a destination address and a source address.

All stations receive the packet and the station with the correct address stores the data contained in the packet with information for all stations. In satellite communication systems, the network is more usually a star configuration, with a single hub and many small earth stations or portable terminals. Inbound packets are received by the hub earth stations and forwarded to their destinations. Early work on random access techniques for radio channel was done at the University of Haawaii, where the system was called Aloha and the known by the generic term packet radio.

ALOHA System Introduction

ALOHAnet, also known as the **ALOHA System**, or simply **ALOHA**, was a pioneering computer networking system developed at the University of Hawaii. ALOHAnet became operational in June, 1971, providing the first public demonstration of a wireless packet data network. ALOHA originally stood for Additive Links On-line Hawaii Area.

The ALOHAnet used a new method of medium access (ALOHA random access) and experimental ultra high frequency (UHF) for its operation, since frequency assignments for communications to and from a computer were not available for commercial applications in the 1970s. But even before such frequencies were assigned there were two other media available for the application of an ALOHA channel – cables and satellites. In the 1970s ALOHA random access was employed in the nascent Ethernet cable based network and then in the Marisat (now Inmarsat) satellite network.

In the early 1980s frequencies for mobile networks became available, and in 1985 frequencies suitable for what became known as Wi-Fi were allocated in the US. These regulatory developments made it possible to use the ALOHA random-access techniques in both Wi-Fi and in mobile telephone networks.

ALOHA channels were used in a limited way in the 1980s in 1G mobile phones for signaling and control purposes. In the late 1980s, the European standardisation group GSM who worked on the Pan-European Digital mobile communication system GSM greatly expanded the use of ALOHA channels for access to radio channels in mobile telephony. In addition SMS message texting was implemented in 2G mobile phones. In the early 2000s additional ALOHA channels were added to 2.5G and 3G mobile phones with the widespread introduction of GPRS, using a slotted-ALOHA random-access channel combined with a version of the Reservation ALOHA scheme first analyzed by a group at BBN

An Overview of ALOHA

One of the early computer networking designs, development of the ALOHA network was begun in September 1968 at the University of Hawaii under the leadership of Norman Abramson along with Thomas Gaarder, Franklin Kuo, Shu Lin, Wesley Peterson and Edward Wheldon.

The goal was to use low-cost commercial radio equipment to connect users on Oahu and the other Hawaiian islands with a central time-sharing computer on the main Oahu campus. The first packet broadcasting unit went into operation in June 1971. Terminals were connected to a special purpose "terminal connection unit" using RS-232 at 9600 bit/s.

The original version of ALOHA used two distinct frequencies in a hub/star configuration, with the hub machine broadcasting packets to everyone on the "outbound" channel, and the various client machines sending data packets to the hub on the "inbound" channel. If data was received correctly at the hub, a short acknowledgment packet was sent to the client; if an acknowledgment was not received by a client machine after a short wait time, it would automatically retransmit the data packet after waiting a randomly selected time interval. This acknowledgment mechanism was used to detect and correct for "collisions" created when two client machines both attempted to send a packet at the same time.

ALOHAnet's primary importance was its use of a shared medium for client transmissions. Unlike the ARPANET where each node could only talk directly to a node at the other end of a wire or satellite circuit, in ALOHAnet all client nodes communicated with the hub on the same frequency. This meant that some sort of mechanism was needed to control who could talk at what time. The ALOHAnet solution was to allow each client to send its data without controlling when it was sent, with an acknowledgment/retransmission scheme used to deal with collisions. This approach radically reduced the complexity of the protocol and the networking hardware, since nodes do not need negotiate "who" is allowed to speak (see: Token Ring).

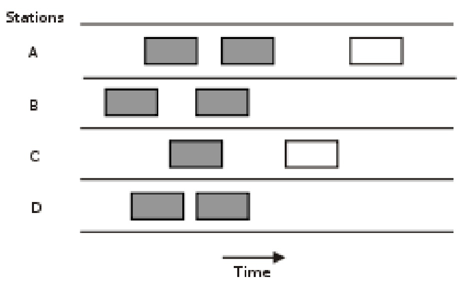
This solution became known as a pure ALOHA, or random-access channel, and was the basis for subsequent Ethernet development and later Wi-Fi networks. Various versions of the ALOHA protocol (such as Slotted ALOHA) also appeared later in satellite communications, and were used in wireless data networks such as ARDIS, Mobitex, CDPD, and GSM.

Also important was ALOHAnet's use of the outgoing hub channel to broadcast packets directly to all clients on a second shared frequency, using an address in each packet to allow selective receipt at each client node. Two frequencies were used so that a device could both receive acknowledgments regardless of transmissions.

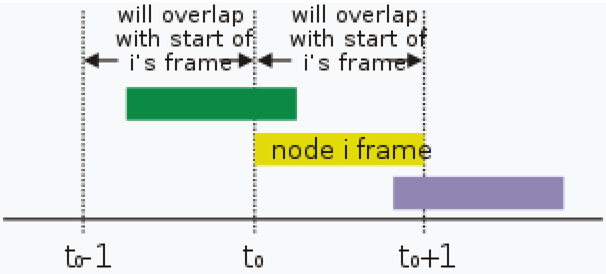
The Aloha network introduced the mechanism of randomized multiple access, which resolved device transmission collisions by transmitting a package immediately if no acknowledgement is present, and if no acknowledgment was received, the transmission was repeated after a random waiting time.

Pure ALOHA Satellite Packet Switching

Stations are allowed random access of the satellite through a common radio frequency band and the satellite broadcasts all received signals on a different frequency band. This enables the stations to perform their duty of monitoring for the presence of packet collisions. The stations implement the simplest protocol; whenever it has a packet to send, it simply does so. In this setup, packets will suffer collision and colliding packets are destroyed. A station determines whether any of its sent packets has suffered a collision or not by monitoring the signal sent by the satellite, after the maximum round-trip propagation time.



Pure ALOHA protocol. Boxes indicate frames. Shaded boxes indicate frames which have collided.

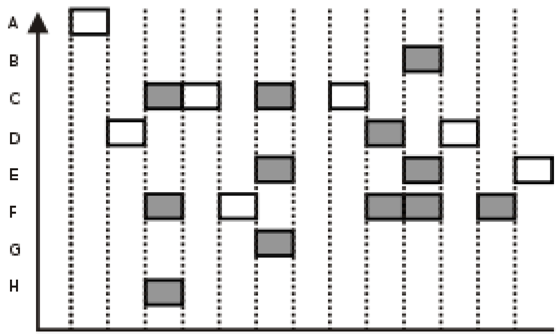


Overlapping frames in the pure ALOHA protocol. Frame-time is equal to 1 for all frames.

If all packets have a fixed duration of T, then a given packet will suffer collision if another station starts to transmit at any time from T before to until T after the start of the packet. This gives a vulnerable period of 2T. The channel utilization can be calculated based on this assumption. The channel utilization, measured as the channel throughput S, in terms of the available channel capacity G is given by S = e^{-2G}. S is maximum and equals 1/2e at G = 1/2, which is approximately 0.18. This value is referred to as the capacity of the pure Aloha channel i.e. 18%.

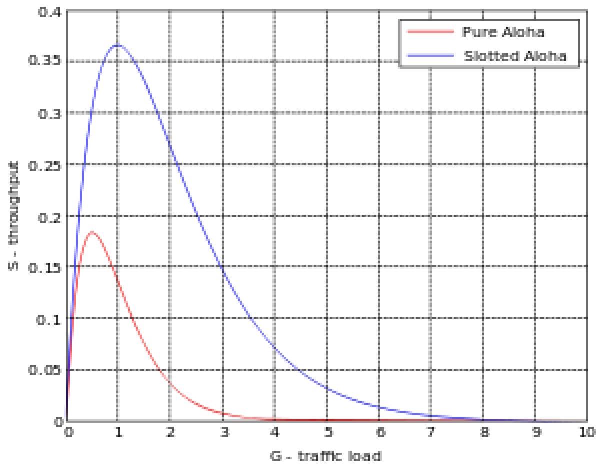
Slotted ALOHA

The Pure Aloha implemented with a slotted channel variation is known as the slotted Aloha protocol. For the slotted Aloha variant, all packets are of equal length and time is slotted. The packet transmission time a full slot. Packets are only transmitted in the next subsequent slot to their arrival slot. It also assumes that there is no buffering, i.e. a station never has more than one packet to transmit in a single time slot, in which case, the station would have needed to buffer one or more packets for subsequent transmission. To accommodate the “no buffering” assumption, it assumes that there is an infinite number of stations, with each new arrival from a new 'source' station. Inevitable collision occurs if more than one station venture to transmit packets in one and the same time slot, and consequently the receivers cannot receive the packets correctly. Successful transmission happens only when there is exactly one packet transmitted in a slot. If no packet is transmitted in a slot, the slot is called idle. If there is a collision, the colliding packets are retransmitted at a later slot after a randomly chosen back-off period. Such packets are also called backlogged packets.



Slotted ALOHA protocol (shaded slots indicate collision)

Slotted ALOHA was developed as an improvement on the efficiency of pure ALOHA.



Comparison of Pure Aloha and Slotted Aloha shown on Throughput vs Traffic Load plot

In this protocol, the channel is divided into slots equal to T (duration of packet transmission). Packet transmission is initiated only at the beginning of a slot. This reduces the vulnerable period in half from 2T to T and improves efficiency significantly by reducing the probability of collision. Channel utilization, measured as throughput S, in terms of the available channel capacity G is given by S = $\boldsymbol{e^{-G}}$. This gives a maximum throughput of 37% at G = 1 i.e. 100% of offered (available) channel capacity.

Tree Algorithm

This is a Collision Resolution Protocol (CRP). As opposed to the instability of the ALOHA protocol, the efforts of CRP are concentrated on resolving collisions as soon as they occur. Here, the fixed-length packets involved in collision participate in a systematic partitioning procedure for collision resolution, during which time new messages are not allowed to access the channel. The stability of the system is ensured provided that the arrival rate of new packets to the system is lower than its collision resolution rate. The tree-type protocols have excellent channel capacity capabilities, but are vulnerable to deadlocks due to incorrect channel observation. The basic form of the Collision Resolution Protocol is the Binary-Tree Algorithm. According to this protocol when a collision occurs in a slot r, all stations that are not involved in the collision wait until the collision is resolved. The stations involved in the collision split randomly into two subsets. The stations in the first subset retransmit in slot r + 1, while those in the second subset wait until all those in the first finish transmitting their packets successfully. If slot r + 1 is either idle or contains a successful transmission, the stations of the second subset retransmit in slot r + 2. If slot r + 1 contains a fresh collision, the procedure is repeated. A collision is resolved when the all the transmitting stations know that all packets involved in the collision have been transmitted successfully. The time interval starting with the original collision (if any) and ending when this collision is resolved is called Collision resolution interval (CRI). The Operation of a binary-tree protocol can also be described by the Stack Algorithm . The performance of the binary-tree protocol can be improved in two ways. The first is to speed up the collision resolution process by avoiding certain, avoidable, collisions. The second is based on the observation that collisions among a small number of packets are resolved more efficiently than collisions among a large number of packets. Therefore, if most CRIs start with a small number of packets, the performance of the protocol is expected to improve. Examples of improved binary-tree protocols are:

1. The Modified binary-tree protocol:- Its operation requires ternary feedback, i.e., the users have to be able to distinguish between idle and successful slots.

2. The Epoch Mechanism:- Its operation models the system in such a way that the CRI starts with the transmission of exactly one packet (yields a throughput of 1) by determining when packets are transmitted for the first time.

3. The Clipped binary-tree protocol:- This improved on the Epoch mechanism by adopting the rule that whenever a collision.