ICC 74

COST THROUGHPUT TRENDS IN COMPUTER NETWORKS USING SATELLITE COMMUNICATIONS*

M. Gerla, W. Chou, H. Frank

Network Analysis Corporation
Beechwood, Old Tappan Road
Glen Cove, New York 11542

ABSTRACT

In this paper, we discuss the design of low cost packet-switched computer networks, in which some of the nodes can communicate via a domestic satellite. Both dedicated (point-to-point) and shared (multiple access) use of satellite bandwidth is considered and appropriate channel and network models for the satellite "subnetwork" are developed. Based on such models, network throughput and delay is evaluated using routing algorithms originally developed for terrestrial packet-switched networks.

Two examples of satellite network design are presented. From the results, some general tradeoffs between design parameters (throughput, line cost, ground station cost, etc) are derived and the economic trends of satellite data networks are discussed.

1. INTRODUCTION

This paper contains the preliminary results of a cost-throughput study regarding the use of satellite links in terrestrial packet-switched communication networks. Concepts and operation of packet-switched networks are not discussed here; ample documentation can be found in the literature.[1, 2, 3, 4] Two schemes for satellite access are considered:

A. Point-to-point connections consisting of full duplex channels between pairs of nodal processors. A point-to-point connection between two nodes, say A and B, consists of terrestrial connection from A to ground station nearest to A, from B to ground station nearest to B, and of a satellite link between the two ground stations.

B. Multiple access connection[5]: special satellite processors installed at each ground station and connected to one or more nodes via terrestrial links provide the interface between the terrestrial network and the satellite channel. Packets arriving to a satellite processor from terrestrial links are transmitted on the satellite channel either in specific time slots (slotted ALOHA) or as soon as they reach the head of the transmitting queue (unslotted ALOHA)[5]. If packets from different stations arrive to the transponder simultaneously, they collide with each other and have to be retransmitted.

In this paper, we determine the tradeoffs of mixed satellite and terrestrial network implementations, and establish some general criteria for network design.

2. SATELLITE ACCESS TECHNIQUES

Packet delay on the satellite channel, utilization and optimal packet routing depend on the access technique used. Point-to-Point access divides satellite channel bandwidth into subchannels, each corresponding to a full duplex point-to-point connection between two given ground stations. Multiple access allows any station to communicate with all other stations using the satellite down link in a broadcast mode. The multiple access techniques are divided into: channel division techniques, where the channel is divided into time or frequency frames, and each frame is preassigned to a given ground station for transmission to the satellite; and channel contention techniques, where each ground station can compete for use of the total channel for transmission to the satellite (e.g., random access ALOHA schemes, reservation schemes, etc.).

It is also possible to implement hybrid access techniques, with one portion of the channel dedicated to point-to-point requirements, and the remaining portion used in a multiple access mode.

3. CHANNEL MODELS

Assume that packets arrive at the ground stations in a Poisson fashion and that packet length is exponentially distributed. The average packet delay for both point to point and multiple access channel division cases has the same expression as the delay for terrestrial channels. In particular[6]:

$$T_i = \frac{1}{\mu C_i} \frac{1}{1-f_i/C_i} + P_s \qquad (1)$$

where:

T_i = delay on i^{th} subchannel (sec)

C_i = capacity of i^{th} subchannel (bits/sec)

f_i = data rate (bits/sec)on i^{th} subchannel

$1/\mu$ = average packet length (bits)

P_s = satellite propagation delay ($\approx$ .27 sec)

The multiple access channel contention case is more difficult to analyze because of the possibility of interference from packets transmitted by different ground stations. Here, consideration is limited to the ALOHA case[5]. The following assumptions are made:

A. The number of ground stations is very large (this leads to a worst case condition).

B. Packets are of constant length

C. Packet arrivals and packet retransmissions are Poisson distributed; and

* This work was supported by the Advanced Research Projects Agency under Contract No. DAHC-15-73-C0135.