TECHNICAL RESEARCH REPORT

Extensions of DBS and Hybrid Internet

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Abstract

There has been a large amount of research dedicated to extending the asymmetric networks provided by receive-only Direct Broadcast Satellite systems like Hughes Network Systems' DirecPC™ product. One way to further develop Direct Broadcast Satellite services and to offset the high initial cost of these systems is to implement techniques that will allow one satellite receiver to act as a gateway for many clients to receive information. This would also help broaden the range of services provided by DBS systems. Besides providing direct-to-home traffic, DBS can be used to distribute bulk traffic to the local-loop distributors (direct-to-curb).

We describe some experiments which extend the DBS system, in particular, the DirecPC™ and DirecTV™ DBS, by using the PC with the satellite receiver as a gateway to connect networks together. We also discuss simple methods of receiving multimedia traffic from the multicast backbone (MBONE) [Cas94] over the satellite link, and distributing it, through this gateway, to end users.

1   Introduction

Direct Broadcast Satellite (DBS) systems provide a method of distributing information to a large number of people over a wide area of coverage. However these benefits are often outweighed by the high cost of the specialized equipment required and the significant complexity of setting it up. Since this overhead is per installation, methods of distributing DBS services from a single receiver out to multiple users, thus amortizing this cost over a large community of users,

are of significant practical interest. Moreover such a redistribution system can also help integrate current networks with DBS, which offers high bandwidth and a natural environment for multicast/broadcast applications. Satellite downlink PCs (hybrid hosts) can, for example, be used to redistribute the data to mobile users by acting as the base station for the mobile clients. Digital technologies make it possible for the "local loop" distribution topology to be anything from Ethernet to ATM to cable TV to wireless.

In this paper we consider some approaches to distributing DBS services in this way and describe two systems that we have implemented to perform this task. We describe a system of distributing multicast MBONE data over a single LAN subnet. We also describe a system of redistributing video and audio data obtained from a DBS system over both an ATM network as well as over Ethernet.

2   Network Architecture

2.1   Hybrid Internet Access Scheme

The basic Hybrid Internet access scheme is shown in Figure 1. The Hybrid Internet (asymmetric) access scheme was first conceived at the Center for Satellite & Hybrid Communication Networks(CSHCN) in 1992. It was further developed at CSHCN and implemented jointly by CSHCN and Hughes Network Systems in the Turbo Internet™ product available from HNS as part of the DirecPC™ series of products. Through various improvements we have been able to consistently obtain 400 kbps return, up from the initial 120 kbps rate. Refer to [FSDB94] [ABD+95] [ASBD96] [ASDB96] [Fal94] for technical details.

The hybrid terminal (host PC) has two network interfaces. One interface is attached to a receive-only VSAT via a special ISA bus PC adapter. The other is a modem attached to a serial port. The host PC uses a modem connection for outgoing traffic while receiving incoming information through the VSAT. The modem connec-
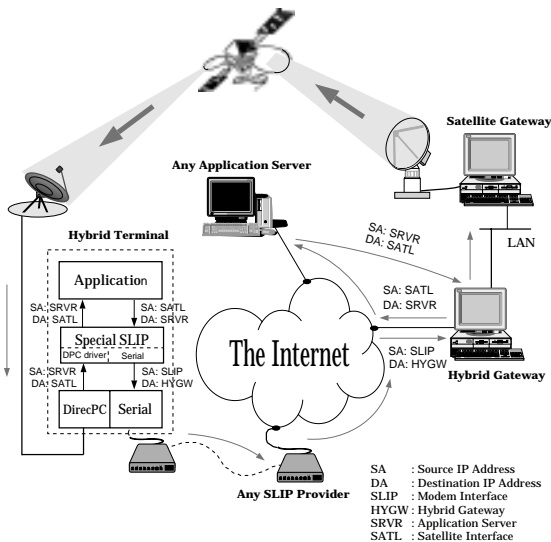
Figure 1: Overview of the Hybrid Internet Access

Figure 2: Extended Network Architecture

tion therefore provides a back-channel into the Internet. This is essential as the VSAT is receive-only. A special Network Device Interface Specification (NDIS) [MC] compliant driver combines the two interfaces and makes them appear as one virtual interface to upper layer TCP/IP protocol stacks [FSDB94] [ASDB96] [ABD+95] [ASBD96] [Fal94]. It achieves this by encapsulating all outgoing packets and tunneling them to the hybrid gateway, which then decapsulates and forwards them to the destination. The hybrid gateway also forwards any replies back to the source over the satellite. The hybrid terminal is attached to the Internet through any Internet service provider using the back-channel interface.

In what follows, to reduce terminology, we shall refer to the single virtual interface consisting of the receive-only satellite interface and the back-channel modem interface as the hybrid interface. We define the term "Remote-LAN" as the subnet or network attached to the DirecPC™ hybrid terminal.

2.2 Extended Network

The augmented network architecture as shown in Figure 2, consists of the host PC, which in addition to the hybrid interface described above, has another network interface which connects it to a LAN. In addition, for some types of services like multicast data, we make use of an " agent" in the Internet which
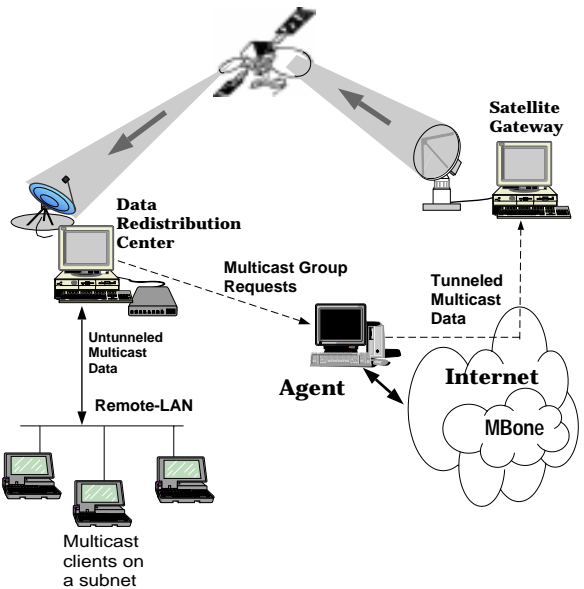
forwards data to the hybrid host via tunneling. The host PC receives data on the satellite interface and forwards it, after the necessary processing, into the Remote-LAN. The host PC uses the back-channel into the Internet, i.e. the modem, to send requests for data either directly into the Internet or to the agent. These requests can originate from either the host PC itself or may originate from the Remote-LAN. The Remote-LAN consists of heterogeneous clients that are networked together using either wireline or wireless technology.

In other words, the host PC relays data between its two interfaces, the hybrid interface and the LAN interface.

3 Terrestrial Extensions of DBS and Hybrid Internet

There are several methods of extending the asymmetric network provided by Direct Broadcast Satellite systems like DirecPC™ [ASDB96] [ZD96][PBS+96]. Currently only the host PC with the satellite decoder/receiver can benefit from the satellite link connectivity. However, the utilization of the satellite link can be further enhanced if the host PC can act as a gateway for a terrestrial wireline or wireless LAN. In order to do this, various techniques have been applied. In the following sections we discuss the use

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of three methods for extending the Hybrid Internet concept [ASDB96], namely Proxies Packet Relaying and Routing. We also discuss our implementation of an Audio/Video redistribution system which forwards Audio/Video streams from DBS over a terrestrial network.

3.1 Proxies

The use of application level proxies is the easiest and simplest to implement as this requires little or no modification to the existing networks on either side of the satellite link. The proxy server application on the host PC receives requests for data from clients on the LAN on proxy ports. The proxy server on the host then takes these requests from the proxy ports and reroutes them to standard protocol ports; it also keeps track of the various proxy connections to the server. These requests for data are then sent out as if they originated from this proxy server PC. The resulting data comes back to this PC over satellite and the proxy application then redirects the data to the appropriate PC. While this approach achieves the desired goal of extending the DBS system, proxies are application specific, so a new proxy must be installed for each application on each client on the Remote-LAN.

We have successfully implemented such a system using a WinGate™ proxy server [Zea] on the host PC serving both wired and wireless clients on the Remote-LAN. In the wireless case, we use the Motorola Altair 10Mbps wireless broadband Ethernet. Such a system has also been successfully and independently implemented at Hughes Research Labs [ZD96].

3.2 Packet Relaying (Forwarding)

Another method of extending the DBS system is via the use of data relaying. Our software has the ability to read frames from the satellite adapter and both read and write frames from the Ethernet adapter. Therefore it can relay data between the satellite adapter card and the LAN adapter card by reading frames from the satellite card and writing them out to the Ethernet card after some processing. In this capacity, the host PC can function as a "Data Redistribution Center" , relaying data between the hybrid interface and the local LAN interface.

The existing Hybrid Internet scheme utilizes the fact that the host PC is the only receiver of data and is mainly a consumer of data. The host PC is therefore expected to generate only small amounts of data. For some applications, this holds true for multiple clients on the Remote-LAN as well. For example, currently, most MBONE users are passive, with little need for a large capacity outgoing link. In this case, the asymmetric capacity host PC can be used as a "data redistribution gateway" and the same multicast data being sent on the satellite link can now have multiple receivers instead of just the single host PC with the satellite receiver/decoder card. Even if there is a high bandwidth alternate link available to the Remote-LAN for data to and from the Internet, this scheme involving redistribution via the host PC can serve to relieve otherwise unnecessary congestion on the regular Internet gateway. Therefore, rather than getting high bandwidth multicast traffic through its regular Internet gateway, a network could be getting it through the satellite [Sec97].

Our implementation provides a way of providing MBONE traffic to multiple clients on the Remote-LAN via the satellite link. The current hardware address filtering mechanism enables the host PC to receive data on a single address assigned to the satellite adapter only. Therefore we use an agent in the Internet to subscribe to requested multicast groups on behalf of members of the Remote-LAN and then tunneling to forward the multicast data to the host PC.

3.2.1 Implementation of the Data Relaying Method

Our prototype implementation of the Data Relaying extension to DBS system runs on a DirecPC™ host PC. The host PC is equipped with the satellite receiver/adapter card, as well as an additional network adapter. The second network adapter enables the host PC to act as the gateway to the satellite link for other computers on that Ethernet segment. The host PC runs Microsoft Microsoft Windows95™, therefore, the implementation uses a virtual device driver(VxD) to receive data from the satellite adapter as well as to read and write packets to the Remote-LAN network adapter. In other operating systems we would use a device driver which allows reads/writes directly to network adapters to implement this approach.

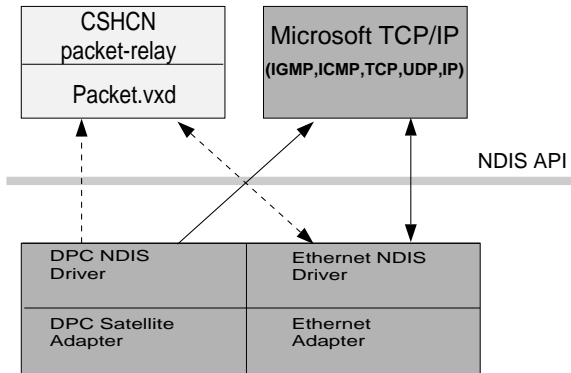As shown in Figure 3, the virtual device driver is

Figure 3: Data Relaying

capable of receiving frames from a NDIS3 compatible network adapter. The satellite receiver card provided with the DirecPC™ system provides a NDIS3 interface to the PC. Therefore the VxD can read "Ethernet-like" frames from the satellite card. At the same time if there are any other LAN adapters in the PC, the VxD can read/write to them as well. Thus the simplest implementation of extending a DBS system would consist of nothing more than reading frames from the satellite adapter and writing them to the LAN adapter. However, before passing on the packet, various headers have to be modified. The headers need to be modified so that the Ethernet source and destination fields will coincide with what the LAN adapters, both in the DirecPC™ machine and in the other LAN clients, are expecting. In this implementation, the VxD reads from the satellite receiver card, processes the packets, and forwards the packets to a LAN adapter and onto the Ethernet segment.

The initial VxD developed proved to be too slow as we were experiencing packet loss on the satellite adapter averaging 60%. Using various techniques such as asynchronous reads and multi-threading, we were able to improve the efficiency of the VxD to almost 99%, making it practical to implement an application using the VxD. The satellite adapter decodes only packets addressed to the IP address assigned to the satellite adapter. To provide a service (like multicast data) to a private LAN, it is necessary to configure the adapter to listen for additional IP addresses that are assigned to the LAN clients or for IP multicast addresses. However, this would require extensive hardware-specific changes in the software manipulating the hardware filtering of incoming packets on the satellite interface. An alternate approach to

this problem is to tunnel packets to the address that the hardware filter is receiving on, and then decapsulate them to reveal the true packet. We implemented the second approach and are currently investigating issues related to implementing this approach without the use of tunneling. The IP tunneling approach requires no DirecPC™ satellite adapter specific API to implement and could be used as is with other satellite adapters, provided the adapter is NDIS compatible. We demonstrated the practicality or our approach by implementing a multicast data redistribution system for the Remote-LAN.

3.2.2 Implementation of Multicast Redistribution In DBS

A system performing multicast redistribution is easy to set up if a program similar to the UNIX mrouted [DTF95] were available for a PC running Microsoft Windows95™. When the mroute daemon is running on a UNIX machine that is multicast capable, it provides a method for a user to add a route to the routing table that tunnels IP traffic to a specified host. The specified host would also be running the mroute daemon and would receive the tunneled IP traffic and decapsulate the data. Mroute can be used when sending multicast data through routers that do not support multicast and it is used extensively in the MBONE. However, mroute communicates using a Distance-Vector Multicast Routing Protocol (DVMRP) [Pus97] and requires a mroute daemon on each side of the tunneled IP path. If a PC version of mroute did exist, we could simply tunnel the MBONE traffic to the PC over the satellite link using software that is already available. Once the data arrived at the satellite interface, it would be decapsulated and the packets would be transferred onto the LAN. Currently there are no commercially available implementations of a mroute daemon for the PC. One reason for this is that the Microsoft Windows95™ operating system does not provide the support necessary to implement a multicast router. In the absence of kernel-level support, the actual routing functions would also have to be implemented outside the kernel, which would be very inefficient.

Therefore we decided to implement a small subset of the functions provided by mroute ourselves. We used a tunnel agent to tunnel multicast data to the unicast address of the DirecPC™ host. The other software portion of the tunnel implementation would be smart packet forwarding software that would rec-

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ognize these tunneled packets, strip the unicast UDP headers to reveal the original multicast packet, build a new Ethernet header corresponding to the multicast address being tunneled, and finally output that packet onto the LAN adapter. In other words, we tunnel multicast packets from a machine in the Internet that can receive the MBONE traffic to the DirecPC™ host as shown in Figure 4.
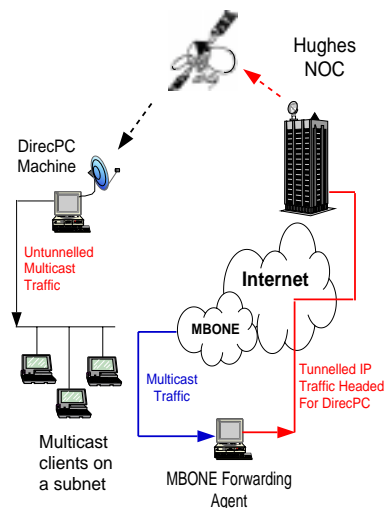

Figure 4: Providing Multicast via Tunneled IP

Since the explanation above only mentions traffic coming into the private LAN this leaves the obvious problem that clients on the private LAN cannot "request" a specific multicast stream. Therefore, the next logical step is to implement a program on the DirecPC™ machine that will listen to IGMP requests on the private LAN and forward them to the tunnel agent as illustrated in Figure 5. The DirecPC™ machine must listen for IGMP requests on its Ethernet interface. Once it sees an IGMP request, it must use its modem connection to the Internet to forward this request to the tunnel agent. The tunnel agent will then subscribe to the appropriate multicast group on behalf of the DirecPC™ machine and its LAN. After it begins to receive multicast traffic from the newly requested multicast group, it must encapsulate the multicast traffic and send it via tunneled IP to the DirecPC™ machine as described in the first stage.

The use of the tunnel agent is fairly similar to the manner in which the MBONE itself operates. However, if we have N DirecPC™ hosts serving as multicast gateways for their private LANs, the tunnel agent must send out N tunneled streams, one to
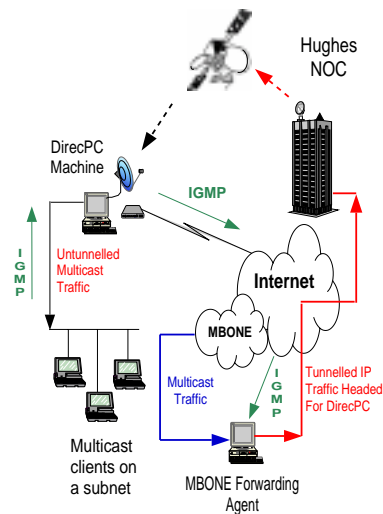

Figure 5: Tunneled Multicast with IGMP Forwarding

each DirecPC™ host. The resulting multicast routing trees are less efficient than if the hybrid hosts were themselves able to listen on a selected multicast address directly. The DirecPC™ hosts filter packets meant for them using a programmable hardware filter. By default the satellite adapter filters only packets which correspond to the IP address given to the satellite adapter card. Therefore, we need to be able to instruct the satellite adapters to listen to additional hardware addresses in order to allow for true multicast. Once we have the capability to do this (using adapter specific API), the DirecPC™ host would send an IGMP-like request on behalf of one of its clients to a machine at the uplink site. This machine would then, as before, subscribe to the corresponding multicast group and start uplinking the traffic on the multicast channel. In this case there is no need to tunnel packets in the manner described above.

Also note that the DBS system is essentially broadcast in nature. Therefore any multicast group membership joins consist of adding a new address to the hardware filter on the satellite adapter. Also a request to join a new group only needs to be sent once. IGMP requires that regular messages be sent from the listeners to confirm that they are still listening to a group. This would not scale to a large number of users as the hybrid gateway would have a very large amount of traffic coming in consisting of nothing but these "still listening" messages. Therefore we propose to use an IGMP-like protocol which would send explicit group-join and group-leave messages. We are

currently working on implementing this IGMP-like protocol, which will enable us to tunnel multicast traffic to a DirecPC™ host when the agent receives a request to join a specific group. The packet forwarding software which will enable us to transfer the multicast packets from the satellite adapter to the Remote-LAN adapter is complete and we can forward mbone traffic to the Remote-LAN via use of tunneling. The implementation of the multicast without the tunneling approach requires infrastructure support from Hughes Network Systems and we plan to coordinate with them to implement it.

3.3 Routing

The third method of extending the Hybrid Internet concept is to make use of routing to make the asymmetric nature of the link transparent. This requires some modifications in either the routing schemes or some modifications to the network configurations. Both these schemes are currently being implemented. The Unidirectional Link Routing (UDLR) working group of the IETF is working on implementing and experimenting with changes to various routing schemes. Work done at INRIA on this subject has proposed changes in the basic routing protocols (RIP, OSPF, and DVMRP) themselves to handle the unidirectional link that is created by introducing a satellite link into the network [DD96]. An alternate proposal from Hughes Research Labs emphasizes the use of tunneling routing messages to affect the necessary changes in the routing tables at both the uplink as well as the downlink computers [Zha96].

However, both approaches do not deal with the inherent asymmetry in the available bandwidth for incoming and outgoing data, and therefore are likely to create a bottleneck at the host PC if they are not modified to account for this. We are currently studying the use of Quality of Service(QoS) based routing in this scenario. It is essential that any routing scheme used in this kind of a network has the ability to specify different routes for different types of traffic. Therefore, for example, the high bandwidth receive-only traffic of the MBONE can come via the satellite link and the low bandwidth traffic can be delivered through some other terrestrial gateway. Also, the satellite link, with its natural broadcast capability, is often preferred for routing multicast traffic due to the lower overhead in terms of capacity wasted in sending multiple copies of the same data. Similarly,

all high bandwidth traffic which needs to be sent out can be routed via the alternate terrestrial gateway and the low bandwidth traffic can be routed via the host PC [Sec97].

The advantage of such an approach, once implemented, is its simplicity and the fact that the asymmetric nature of the link remains transparent to the rest of the network. However, this approach requires the ability to receive unicast packets bound for different addresses or for an entire subnet through the hybrid interface, which was not available to us at the time of this experiment. It also requires that QoS-based routing be widely implemented in the Internet.

4   Video Redistribution

DBS systems can not only provide Internet access, but can also serve as distribution systems for different kinds of multimedia content and indeed for any other kind of digital data. The convergence of digital multimedia services DBS and data services DBS is a natural outcome of this trend, as seen in the recent merging of DirecTV™ and DirecPC™ receivers. In some cases it may be advantageous to implement a terrestrial redistribution for these multimedia services as well as the Internet services. Distribution of video streams is expected to be a major application of future high speed broadband networks. A lot of this traffic is expected to be multicast traffic, flowing over hybrid satellite-terrestrial networks. Various applications which are likely to make use of such technology are: Corporate Training, Video Conferencing, Video-on-demand distribution services, Telemedicine, and Distance Learning.

4.1   Implementation of Video Redistribution System

We have developed an application to demonstrate one way in which this redistribution of video and audio streams can be accomplished. It provides a testbed for experimental studies on how various factors, like compression type, available bandwidth, and congestion affect the performance of such video distribution systems.

Our implementation was developed on a SUN SPARC ULTRA workstation equipped with both an Ethernet card and a FORE ATM adapter as seen in Figure 6. The sample audio and video streams from the DSSTV set-top box was fed into the video card
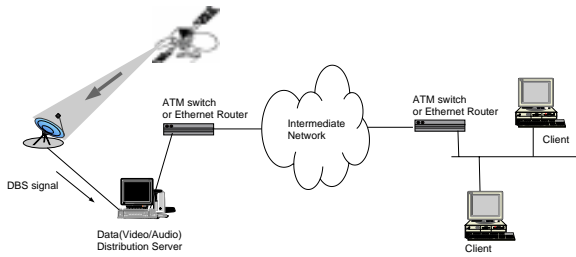
Figure 6: Video Distribution Implementation

and the audio port on the workstation. The output of the DirecTV™ set-top box provides us with a NTSC output. This input signal was then re-sampled and the resulting data packets, consisting of a sampled NTSC signal were then compressed, packetized and transmitted over the network to a client application. The audio packets were transmitted without any compression. The re-sampled data was transmitted over both ATM as well as Ethernet. Our implementation allows us to use various compression schemes like Cell-B, JPEG and MPEG. Compression at the video redistribution center is important for conserving bandwidth and is independent of the compression scheme used for transmission in the DBS system. We demonstrated both unicast and multicast video redistribution using UDP/IP over Ethernet. We were also able to show unicast over native ATM, and simulated multicast redistribution by having multiple unicast connections. We were also able to use both classical IP as well as FORE-IP over ATM to demonstrate video distribution via UDP/IP over ATM.

5   Conclusion

There are several approaches to extending the benefits of satellite connections provided by DBS services to more than just a single client. Being able to distribute the benefits to more than one client enhances the utilization of the DBS channel and makes the DBS services more cost effective for the consumer. We have presented three possible ways of achieving this, and it can be seen that these are arranged in order according to their simplicity. While the proxy approach would treat the hybrid interface and each class of application using it as a special case, the routing approach tries to seamlessly integrate the hybrid interface into existing networks as just another network interface. The data relaying method tries to achieve

an intermediate position, in view of the practical constraints of the available hardware device drivers and current Internet routing technologies.

Video redistribution over a terrestrial network raises various issues regarding compression techniques used, bandwidth availability and scalability with respect to providing multiple channels within a given bandwidth constraint. We describe a testbed for experimenting and developing means of enhancing services provided by DBS systems. Such extensions of current DBS and Hybrid Internet technologies are likely to play an important role in the growth of DBS systems as well as aid in their integration into current systems.

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