NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Enginnering

MULTIPLE ACCESS METHODS FOR SATELLITE COMMUNICATION

Graduation Project
EE-400

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In the outcome of hardly investigation I am herely able to present this project, on Multiple access of satellite communication.

A special of thanks to.........

A big part of acknowlegment is due to Mr.İzzet Ağören,my scheme adviser and beloved teacher,without whom assistance I would not able to complete this scheme work.he gave me chance for expressing our views and my application of studies in a prstical way on SATCOM to prove our abilities in this scheme.I would also like to oblige for him assistance supervision all the ways in making my scheme. I actually impressed the personality of my teacher who gave me his expensive time and I am not able to complete this project without my teacher help.

S. MEMDUH ŞAHİNOĞLU

T.İZZET AĞÖREN

INTRODUCTION

The multiple access is not a very old topic and especially it is developed inrecently much and it can even be developed.It has been determined to military satellitecommunication practices,because it is a secure satcom techniques which is in general to supply access.

Multiple access protocols are used in conjunction with many different types of broad-cast channels. They have been used for satellite and wireless channels, whose nodes transmit over a common frequency spectrum. They are currently used in the upstream channel for cable access to the Internet .And they are extensively used in local area networks(LANs).

Chapter one concerned the design of improved wireless radio networks. The mobile or indoor radio channel is characterized by 'multipath reception': The signal offered to the receiver contains not only a direct line-of-sight radio wave, but also a large number of reflected radio waves. These reflected waves interfere with the direct wave, which causes significant degradation of the performance of the network. A wireless network has to be designed in such way that the adverse effect of these reflections is minimized. Another critical design objectiven is high spectrum efficiency. The latter should ensure that the network can accommodate as many users possible within a given frequency band.

Chapter two presents TDMA as a technology for digital transmission of radio signals for example, a mobile telephone and a radio base station. In TDMA, the frequency band is split into a number of channels, which are stacked into short time units, so that several calls can share a single channel without interfering with one another. TDMA is used by the GSM digital mobile standard.

In chapter three : The system provides two-way communications between Gateway Hub Earth Stations (GHESs) and end-user Remote Terminals (RTs), with the Network Management Station (NMS) managing the proper operation of the network. Furthermore, the GHESs provide gateway between the Eutelsat DSAT 160 network and external networks (e.g. PSTN, PABX). In this way, any RT user can communicate with an end-user outside the DSAT 160 network

In chapter four: Slotted ALOHA is highly decentralized, as each node detects collisions and independently decides when to retransmit. (Slotted ALOHA does, however, require the slots to be synchronized in the nodes; we'll shortly discuss anunslotted version of the ALOHA protocol, as well as CSMA protocols; noe of which require suchynchronization and are therefore fully decentralized.) Slotted ALOHA is also an extremely simple protocol.

In chapter five: Multiple access protocols are used in conjunction with many different types of broadcast channels. They have been used for satellite and wireless channels, whose nodes transmit over a common frequency spectrum.

In chapter six: Satellite categorisation is based upon the type of orbit and area of coverage.When choosing an orbit for a communications satellite it is generally best to avoid the regions around the earth of intense radiation, the Van Allen belts, where high-energy particles from the sun are entrapped by the Earth's magnetic field.

CHAPTER 1

BACKGROUND

This project addresses the design of improved wireless radio networks. The mobile or indoor radio channel is characterized by 'multipath reception': The signal offered to the receiver contains not only a direct line-of-sight radio wave, but also a large number of reflected radio waves. These reflected waves interfere with the direct wave, which causes significant degradation of the performance of the network. A wireless network has to be designed in such way that the adverse effect of these reflections is minimized. Another critical design objective is high spectrum efficiency. The latter should ensure that the network can accommodate as many users possible within a given frequency band.

The effects of (multipath) radio propagation, modulation, and coding and signal processing techniques on the spectrum efficiency and performance of wireless radio networks are studied, in particular Orthogonal Frequency Division Multiplexing (OFDM) and related transmission methods.

Most conventional modulation techniques are sensitive to intersymbol interference unless the channel symbol rate is small compared to the delay spread of the channel. OFDM is significantly less sensitive to intersymbol interference, because a special set of signals is used tobuild the composite transmitted signal. The basic idea is that each bit occupies a frequency- time window which ensures little or no distortion of the waveform. In practice it means that bits are transmitted in parallel over a number of frequency nonselective channels. This technique is for instance used in digital audio broadcasting (DAB).

1.1. THE ORTHOGONAL MULTI-CARRIER CDMA

There are many equivalent ways to describe MC-CDMA:

1. MC-CDMA is a form of CDMA or spread spectrum, but we apply the spreading in the frequency domain (rather than in the time domain as in Direct Sequence CDMA).
2. MC-CDMA is a form of Direct Sequence CDMA, but after spreading, a Fourier Trans form (FFT) is performed.
3. MC-CDMA is a form of Orthogonal Frequency Division Multiplexing (OFDM), but we first apply an orthogonal matrix operation to the user bits. Therefor, MC-CDMA is sometimes also called "CDMA-OFDM".
4. MC-CDMA is a form of Direct Sequence CDMA, but our code sequence is the Fourier Transform of a Walsh Hadamard sequence.
5. MC-CDMA is a form of frequency diversity. Each bit is transmitted simultaneously (in parallel) on many different subcarriers. Each subcarrier has a (constant) phase offset. The set of frequency offsets form a code to distinguish different users.

P.S. Our MC-CDMA is NOT the same as DS-CDMA using multiple carriers.

1.2. THE ADVANTAGES OF MC-CDMA

- Compared to Direct Sequence (DS) CDMA.

- DS-CDMA is a method to share spectrum among multiple simultaneous users.

Moreover, it can exploit frequency diversity, using Direct Sequence (DS) receivers. However, in a disp ersive multipath channel, DS-CDMA with a spread factor N can accommodate N simultaneous users only if highly complex interference cancellation techniques are used. In practice this is difficult to implement. MC-CDMA can handle N simultaneous users with good BER, using standard receiver techniques.

- Compared to OFDM.

To avoid excessive bit errors on subcarriers that are in a deep fade, OFDM typically applies coding. Hence, the number of subcarriers needed is larger than the number of bits or symbols transmitted simultaneously. MC-CDMA replaces this encoder by an NxN matrix operation. Our initial results reveal an improved BER. See: Derivation

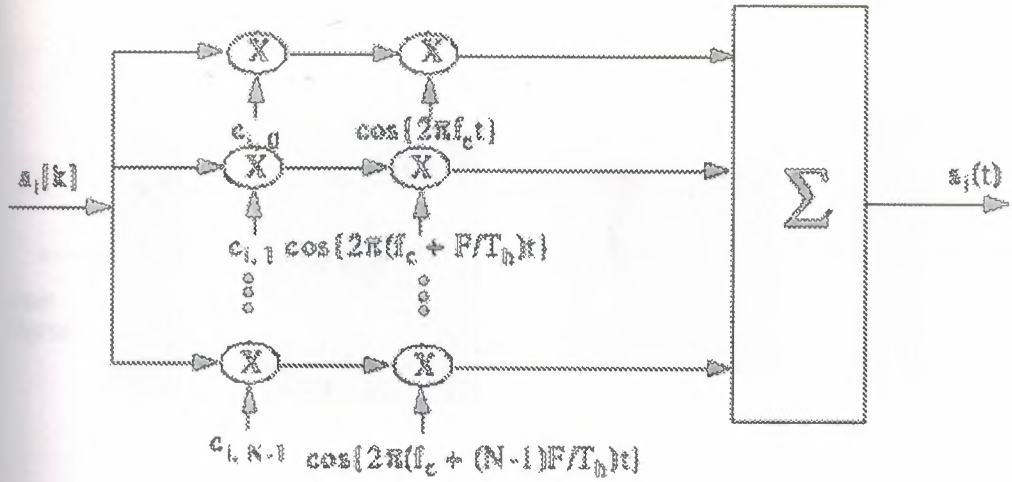


Figure1.1:The Possible Transmitter Implementation

This figure1.1 shows the possible implementation of an Multi-Carrier spread-spectrum transmitter. Each bit is transmitted over *N* different subcarriers. Each subcarrier has its own phase offset, determined by the spreading code. Code Division Multiple Access systems allow simultaneous transmission of several such user signals on the same set of subcarriers. In the downlink multiplexer, this can be implemen ted using an Inverse FFT and a Code Matrix.

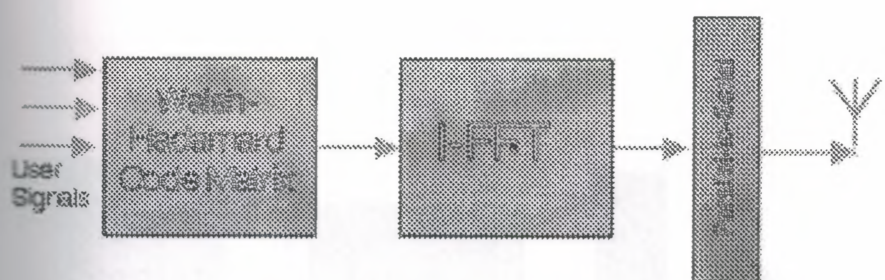


Figure 1.2: FFT implementation of an MC-CDMA

This figure 1.2 shows FFT implementation of an MC-CDMA base station multiplexer and transmitter.

1.3. MC-CDMA AS A SPECIAL CASE OF DS-CDMA

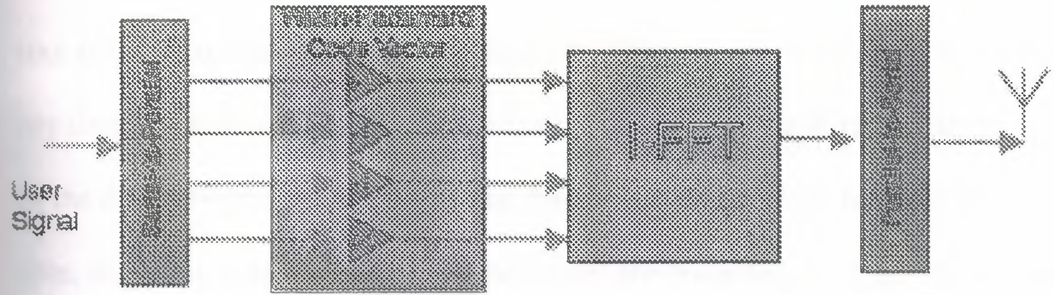


Figure 1.3: possible implementation of a Multi-Carrier spread-spectrum transmitter

Each bit is transmitted over *N* different subcarriers. Each subcarrier has its own phase offset, determined by the spreading code. Note that the code is fixed over time, but only varies with subcarrier frequency.

The above transmitter can also be implemented as a Direct-Sequence CDMA transmitter, i.e., one in which the user signal is multiplied by a fast code sequence. However, the new code sequence is the Discrete Fourier Transform of a binary, say, Walsh Hadamard code sequ ence, so it has complex values.

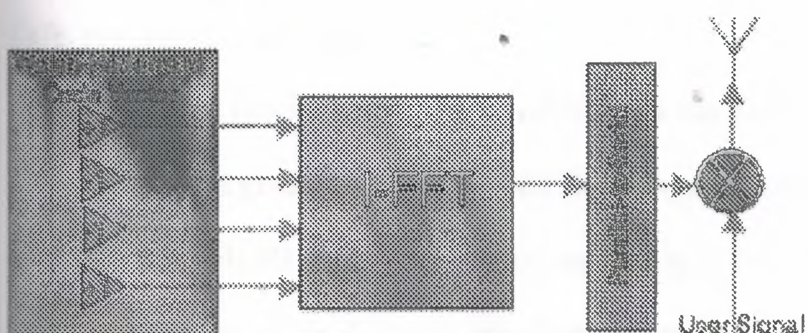


Figure 1.4: Alternative implementation of a Multi-Carrier spread-spectrum

This figure 1.4 shows the alternative implementation of a Multi-Carrier spread-spectrum transmitter, using the Direct sequence principle.

1.4. CARRIER SENSE MULTIPLE ACCESS/COLLISION DETECT (CSMA/CD)

Carrier Sense Multiple Access/Collision Detect (CSMA/CD) is the protocol for carrier tran smission access in Ethernet networks. On Ethernet, any device can try to send a frame at any time. Each device senses whether the line is idle and therefore available to be used. If it is, the device begins to transmit its first frame. If another device has tried to send at the same time, acollision is said to occur and the frames are discarded. Each device then waits a random amo- unt of time and retries until successful in getting its transmission sent.

A new generation of fast, data-rich, multimedia services accessed instantly over mobile hand-sets is emerging worldwide. The technology which makes this possible is named 3G, or third-generation telecommunications. Every telecom operator, developer and vendor in the world is going to be affected by this technology as telecommunication evolves towards a third generation of networks, services and applications.

The WCDMA standard provides seamless global evolution from today's GSM with support of the worlds' largest mobile operators. This global choice on the part of so many operators is the result of WCDMA technology's robust capabilities, being built on open standards, wide ranging mobile multimedia possibility, and vast potential economies of scale.

Safe, manageable evolution

The good news is that the transition towards this exciting new technology will be safe, mana- geable and gradual. Partnering with Ericsson, operators can tailor their network evolution tow ards 3G telecommunications according to their business needs.

3G is an evolution within the telecommunications industry and *not* a revolution. On the one hand, the evolutionary path to 3G will be carefully managed and profitable for operators while on the other, smooth and seamless for users.

Working with Ericsson, operators can keep their core technologies and investments in place, while enhancing their systems for the third generation mobile multi-media services. Operators will have maximum reuse of their original investments while moving towards full 3G services at their own speed, according to their own needs.

A profitable, low-risk, customized evolution

Because WCDMA technology is evolved from existing GSM technology, operators do nothave to transform their networks when they move from 2G to 3G, or throw infrastructure away and start from scratch. The move to 3G optimizes operators' existing 2G infrastructure, enabling it to co-exist profitably with the new WCDMA system. The operators' GSM equipment - incrementally enhanced by WCDMA - can continue to offer services and generate revenues within the WCDMA 3G network. The old and the new technology complement each other, forming a highly flexible, seamless network system.

Seamless evolution, seamless networks, seamless revenues

WCDMA will dominate 3G and is fully compatible with GSM, but GSM operators can also choose to deploy EDGE in their existing GSM spectrum - alone or together with theirWCDMA networks. EDGE is defined as a 3G technology, according to IMT-2000. Most of theworld's operators have chosen to use WCDMA as their preferred 3G technology.

1.5. TDMA TO GSM/WCDMA OR CDMA 2000

TDMA operators have two migration paths to choose from. They can migrate to GSM and from there on to WCDMA, or they can go via CDMA to CDMA2000. Ericsson is a proven and experienced partner in TDMA/ CDMA technology as well as GSM.

PDC to WCDMA

PDC networks, used in Japan, will evolve into WCDMA, whereas 2G cdmaOne (or IS-95) will progress to CDMA2000. Ericsson is one of only two suppliers in the world who provide

PDC infrastructure.

Making evolution safe, making migration easy

All telecom roads lead to 3G. Because Ericsson offers a full range of second and thirdgenera tion solutions it can ensure that whatever 2G system operators are using, their core networks and competencies can be updated and retained during migration to 3G.

Operators can implement the capacity they need when they need it, progressing towards 3G safe in the knowledge that their evolutionary path will be smooth and profitable.

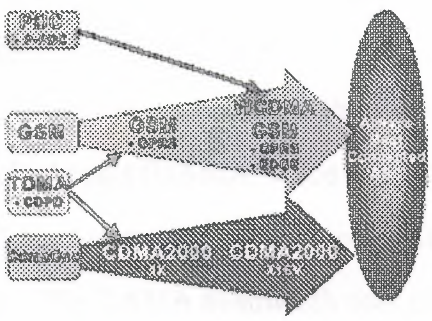


Figure 1.5:Multi-Frequency Time Division Multiple Access (MF-TDMA)

This figure 1.5 shows Multıple-Frequency Time Division Access.

Multi-Frequency Time Division Multiple Access. Aramiska uses different frequencies to trans mit data via satellite. MF-TDMA allows signals to "search" for available slots between the dif ferent frequencies and send the data via these available slots.

Example

Eutelsat

System Overview

The DSAT 160 is based on Single-Channel-per-Carrier (SCPC) and Demand Assigned Multip le Access (DAMA) technology which provides an effective and attractive method to support thin to medium telephony traffic while reducing space segment and ground segment costs. Instead of dedicated point-to-point links, the system assigns the satellite resources on demand. A much smaller amount of satellite bandwidth can be shared, thus taking advantage of the ran dom and occasional nature of telephony traffic. Since the DAMA system assigns bandwidth on a per call basis, full Mesh single hop connectivity is possible.

Traffic Topology

The DSAT 160 system can support both Pre-Assigned Multiple Access (PAMA) and Demand Assigned Multiple Access (DAMA) voice and data circuits. All circuits use one satellite hop and can be configured with any combination of Mesh (remote-to-remote) or Star (remote-to-hub) connectivity. The DAMA bandwidth pool can be divided into three levels of call priority (high, medium and low). The highest priority is reserved for the most critical channels while the lowest is for typical DAMA calls. The extreme flexibility of this system will support any traffic plan.

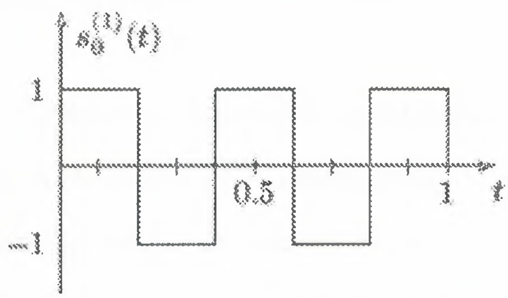
CHAPTER 2

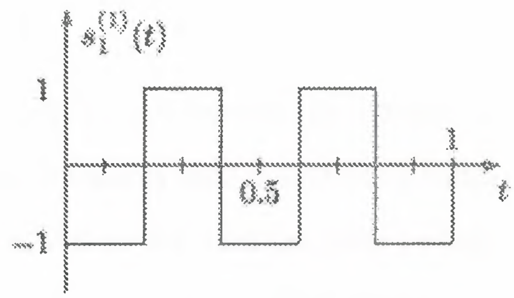
2.1. SPREAD SPECTRUM MULTIPLE ACCESS

In a spread spectrum communication system users employ signals which occupy a significantly larger bandwidth than the symbol rate. Such a signalling scheme provides some advantages which are primarily of interest in secure communication systems, e.g., low probability of intercept or robustness to jamming. In this problem we explore the inherent multiple access capability of spread spectrum signalling, i.e., the ability to support simultaneous transmissions in the same frequency band.

In the sequel, assume that the communication channel is an additive white Gaussian noise channel with spectral height $No/2$.

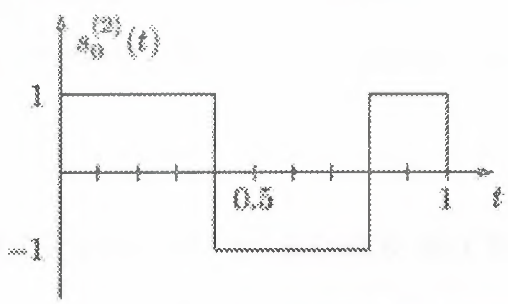
1. One user employs the following signal set to transmit equally likely binary symbols

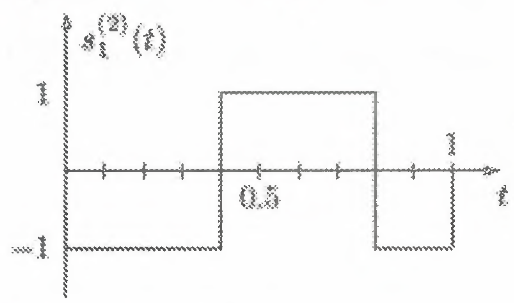




Draw a block diagram of the receiver which minimizes the probability of a bit error for this signal set.

1. Compute the probability of error achieved by your receiver.
2. Now, a second users transmits one of the following signals with equal probability





Both signals are transmitted simultaneously, such that the received signal is given by

$$R_t = A_1 s_i^{(1)}(t) + A_2 s_j^{(2)}(t) + N_t, \quad (1)$$

where N_t is the noise process and $i, j \square \{0, 1\}$ indicate which symbol each of theus-ers is transmitting. We are interested in receiving the first user's signal in the presen-ce of the second (interfering) user.

Find the probability of error of your receiver from part (a) for distinguishing between $S_0^{(1)}(t)$ and $S_1^{(1)}(t)$ if the received signal is given by (1). Which value does theprob ability of error approach if the amplitude A_2 of the interfering user approaches ∞.

3. Find the minimum probability of error receiver for distinguishing between $S_0^{(1)}(t)$ and
4. $S_1^{(1)}(t)$ in the presence of the interfering signal $S_j^{(2)}(t)$, i.e., if the signal is received
5. given by (1). *Note:* You do not need to find the probability of error for this receiver.
6. Indicate the locations of the relevant signals and the decision regions for your receiver from part (d) in a suitably chosen and accurately labeled signal space. Indicate also the decision boundary formed by the receiver from part (a).

2.2. TIME DIVISION MULTIPLE ACCESS

TDMA a technology for digital transmission of radio signals between, for example, a mobile telephone and a radio base station. In TDMA, the frequency band is split into a numb-er of channels, which are stacked into short time units, so that several calls can share a single channel without interfering with one another. TDMA is used by the GSM digital mobile standard.

TDMA is based on the IS-136 standard. It is one of the world's most widely deployed digital wireless systems. It provides a natural evolutionary path for analog AMPS networks, offers efficient coverage and is well suited to emerging applications, such as wireless virtual private networks (VPNs), and is the ideal platform for PCS (Personal Communication Servic-es).

2.3. CODE DIVISION MULTIPLE ACCESS

CDMA (Code Division Multiple Access) is a"spread spectrum" technology. By spre-ading information contained in a particular signal over a much greater bandwidth than theoriginal signal, it offers TDMA operators significant increases in coverage. CDMA enhances TDMA to a predominantly 2G digital system. With CDMA operators canenlarge their capacity by up to eight to ten times and offer users better call quality. (also known as D-AMPS) is.

Offering high quality voice service, advanced features and RF management, Nortel Networks TDMA solutions are the choice of many successful network operators around the world. Nortel Net-works comprehensive TDMA Radio Access and Circuit Switching portfoli os offer :

- Support for both 800 MHz and 1900 MHz
- Cost savings through industry-leading capacity, top-rated RF capabilities and advanced OAM&P functionality
- Voice and data services that help increase revenue and attract and retain customers
- The industry's most reliable switching platform (according to the FCC's 2001 ARMIS Report): Nortel Networks DMS-MTX.
- Industry-leading audio quality and network performance, which decreases dropped and blocked calls, reduces system interference, and helps increase end-user satisfaction and loyalty.

2.4. MULTI-CARRIER CDMA

Prof. Jean-Paul Linnartz started his research on Multi Carrier Code Division Multiple Access (MC-CDMA) in 1992 at the Department of Electrical Engineering and Computer Sciences, University of California at Berkeley. The first research results were published in 1993 at PIMRC in Yokohama. This page has been compiled from material presented in Wireless Communication, The Interactive Multimedia CD ROM.

CHAPTER 3

3.1. NETWORK ARCHITECTURE

The system provides two-way communications between Gateway Hub Earth Stations (GHESs) and end-user Remote Terminals (RTs), with the Network Management Station (NMS) managing the proper operation of the network. Furthermore, the GHESs provide gateway between the Eutelsat DSAT 160 network and external networks (e.g. PSTN, PABX). In this way, any RT user can communicate with an end-user outside the DSAT 160 network.

Applications

The applications of the DSAT 160 are:

- Rural telephony:
  - Single pay-phone or phone shop
  - Widely spread subscribers
  - Small villages (wired or wireless sub-networks)
- Business communications using multi-channel terminals:
  - Connection to PABX
  - LAN interconnection
  - Voice, fax, data, email, internet access
- Portable communications:
  - Prospecting companies
  - Humanitarian organisations

Network Architecture

Three basic elements can be distinguished in the system:

- the single Network Management Station (NMS) is responsible for the overall management of the network, including resource management and monitoring and cont rol of the different network components.
- the Gateway Hub Earth Stations (GHESs) provides the interface of Eutelsat DSAT

160 with external networks (e.g. PSTN, PABX). There may be one or more GHESs in one or many countries, depending on the network configuration. The simplest network topology consists of one GHES and several RTs forming a star. In this case, the GHES and NMS may be co-located and hence share the RF front-end.

This concept can be generalised to a multistar network, where every sub-network, com posed of a number of RTs, registered to their own GHES.

◦ the Remote Terminals (RTs). Fixed / transportable RTs are foreseen in the EUTELSAT DSAT 160 network. The fixed RTs provide the same basic services as the portable RTs. In addition, by having multiple users simultaneously sharing the RT capacity, other ,more capacity demanding services, may also be supported by a fixed RT

3.2. MULTIPLE ACCESS PROTOCOLS AND LANS

In the introduction to this chapter, we noted that there are two types of network links: point-to-point links, and broadcast links. A **point-to-point link** consists of a single sender on one end of the link, and a single receiver at the other end of the link. Many link-layer protocols have been designed for point-to-point links; PPP (the point-to-point protocol) and HDLC are two such protocols that we'll cover later in this chapter. The second type of link, a **broadcast link**, can have multiple sending and receiving nodes all connected to the same, single, shared broadcast channel. The term "broadcast" is used here because when any one node trans mits a frame, the channel broadcasts the frame and each of the other nodes receives a copy. Ethernet is probably the most widely deployed broadcast link technology; we'll cover Ethernet in detail in the later chapter. In this section we'll take step back from specific link layer protocols and first examine a problem of central importance to the data link layer: how to coor dina te the access of multiple sending and receiving nodes to a shared broadcast channel the socalled **multiple access problem**. Broadcast channels are often used in **local area net works** (LANs), networks that are geographically concentrated in a single building (or on a corporate or university campus). Thus, we'll also look at how multiple access channels are used in LANs at the end of this Chapter.

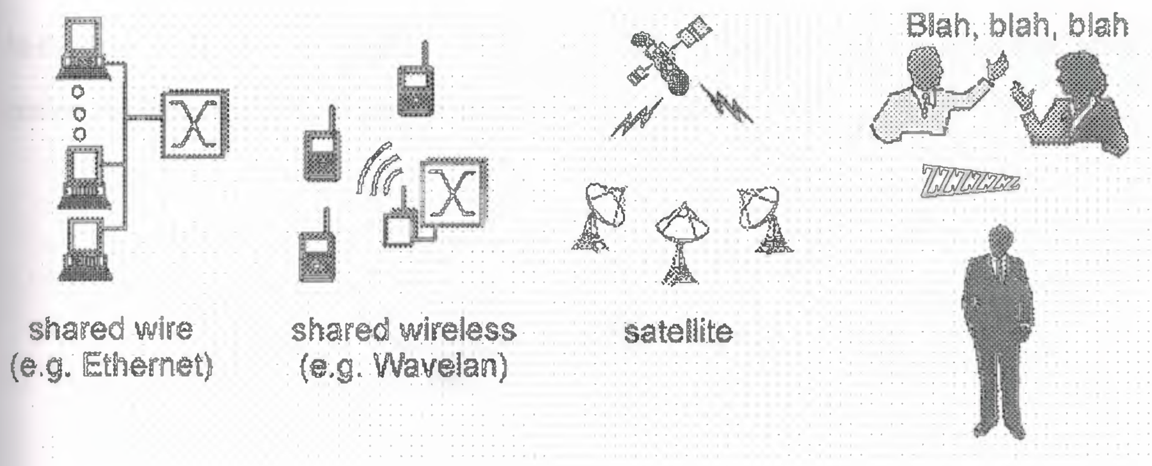


Figure 1.6: Various multiple access channels

We are all familiar with the notion of broadcasting, as television has been using it since its invention. But traditional television is a one-way broadcast (i.e., one fixed node transmitting to many receiving nodes), while nodes on a computer network broadcast channel can both send and receive. Perhaps a more apt human analogy for a broadcast channel is a cocktail party, where many people gather together in a large room (the air providing the broadcast medium) to talk and listen. A second good analogy is something many readers will be familiar with - a classroom - where teacher(s) and student(s) similarly share the same, single, broadcast medium. A central problem in both scenarios is that of determining who gets to talk (i.e., transmit into the channel), and when. As humans, we've evolved an elaborate set of protocols for sharing the broadcast channel ("Give everyone a chance to speak." "Don't speak until you are spoken to." "Don't monopolize the conversation." "Raise your hand if you have question." "Don't interrupt when someone is speaking." "Don't fall asleep when someone else is talking.").

Computer networks similarly have protocols - so-called multiple access protocols - by which nodes regulate their transmission onto the shared broadcast channel. As shown in Figure 1.6 , multiple access protocols are needed in a wide variety of network settings, including both wired and wireless local area networks, and satellite networks. Figure 1.7 takes a more abstract view of the broadcast channel and of the nodes sharing that channel. Although technically each node accesses the broadcast channel through its adapter, in this section we will refer to the node as the sending and receiving device. In practice, hundreds or even thousands of nodes can directly communicate over a broadcast channel.

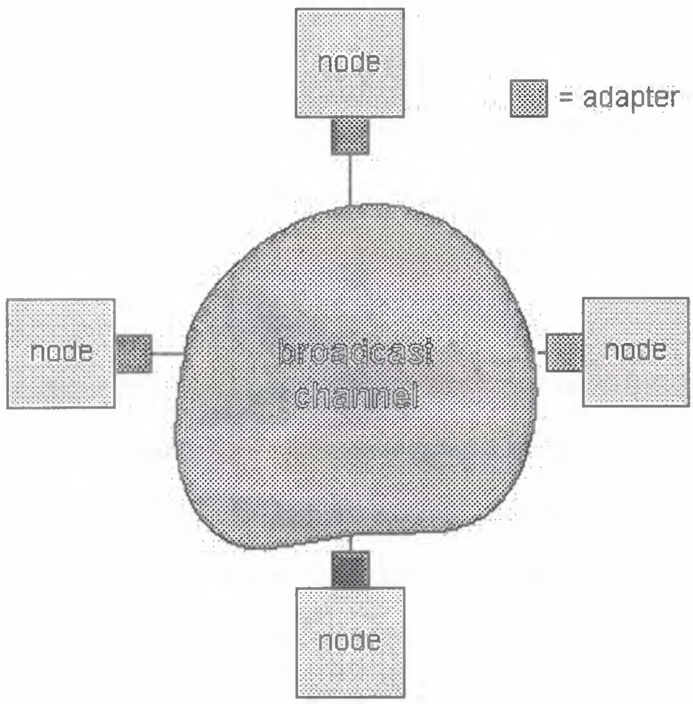


Figure 1.7: A broadcast channel interconnecting four nodes

Because all nodes are capable of transmitting frames, more than two nodes can transmit frames at the same time. When this happens, all of the nodes receive multiple frames at the same time, that is, the transmitted frames **collide** at all of the receivers. Typically, when there is a collision, none of the receiving nodes can make any sense of any of the frames that were trans mitted; in a sense, the signals of the colliding frame become inextricably tangled together. Thus, all the frames involved in the collision are lost, and the broadcast channel is wasted during the collision interval. Clearly, if many nodes want to frequently transmit frames, many transmissions will result in collisions, and much of the bandwidth of the broadcast channel will be wasted.

In order to ensure that the broadcast channel performs useful work when multiple nodes are active, it is necessary to somehow coordinate the transmissions of the active nodes. This coordination job is the responsibility of the **multiple access protocol**. Over the past thirty years, thousands of papers and hundreds of Ph.D. dissertations have been written on multiple access protocols; a comprehensive survey of this body of work is Furthermore, dozens of different protocols have been implemented in a variety of link-layer technologies.

Nevertheless, we can classify just about any multiple access protocol as belonging to one of three categories: **channel partitioning protocols**, **random access protocols**, and **takingturrns protocols**. We'll cover these categories of multiple access protocols in the following three subsections. Let us conclude this overview by noting that ideally, a multiple access protocol for a broadcast channel of rate R bits per second should have the following desirable character istics:

1. When only one node has data to send, that node has a throughput of R bps.
2. When M nodes have data to send, each of these nodes has a throughput of R/M bps. This need not necessarily imply that each of the M nodes always have an instantaneous rate of R/M, but rather that each node should have an average transmission rate of R/M over some suitably-defined interval of time.
3. The protocol is decentralized, i.e., there are no master nodes that can fail and bring down the entire system.
4. The protocol is simple, so that it is inexpensive to implement.

3.3.CHANNEL PARTITIONING PROTOCOLS

Recall from our early discussion back in previous chapter, that Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM) are two techniques that can be used to partition a broadcast channel's bandwidth among all nodes sharing that channel. As an example,suppose the channel supports N nodes and that the transmission rate of the channel is R bps.

TDM divides time into **time frames** (not to be confused the unit of data, the frame, at the data link layer) and further divides each time frame into *N* **time slots**. Each slot time is then assiged to one of the *N* nodes. Whenever a node has a frame to send, it transmits the frame's bits during its assigned time slot in the revolving TDM frame. Typically, frame sizes are chosen so that a single frame can be transmitting during a slot time. Figure 1.8 shows a simple four-node TDM example. Returning to our cocktail party analogy, a TDM-regulated cocktail party would allow one partygoer to speak for a fixed period of time, and then allow another partygoer to speak for the same amount of time, and so on. Once everyone has had their chan ce to talk, the pattern repeats.

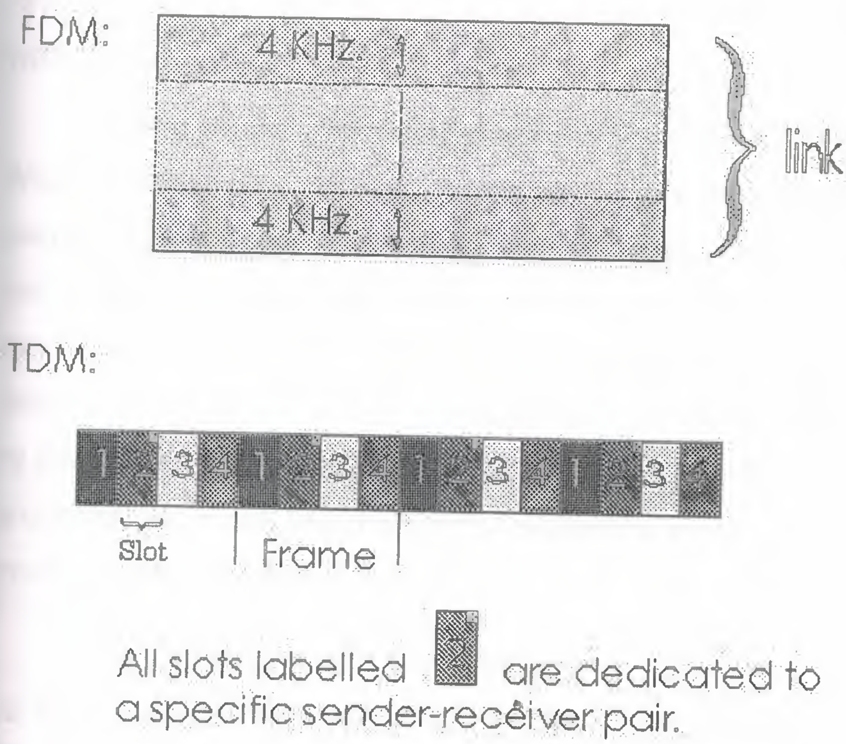


Figure 1.8: A four-node TDM and FDM example

TDM is appealing as it eliminates collisions and is perfectly fair: each node gets a dedi cated transmission rate of *R/N* bps during each slot time. However, it has two major drawbac- ks. First, a node is limited to this rate of *R/N* bps over a slot's time even when it is the only de with frames to send. A second drawback is that a node must always wait for its turn in the transmission sequence - again, even when it is the only node with a frame to send.

Imagine the partygoer who is the only one with anything to say (and imagine that this is the even rarer circumstance where everyone at the party wants to hear what that one person has to say). Clearly, TDM would be a poor choice for a multiple access protocol for this parti- cular party.

While TDM shares the broadcast channel in time, FDM divides the *R* bps channel into different frequencies (each with a bandwidth of *R/N*) and assigns each frequency to one of the *N*nodes. FDM thus creates *N* "smaller" channels of *R/N* bps out of the single, "larger" *R* bps channel. FDM shares both the advantages and drawbacks of TDM. It avoids collisions and divides the bandwidth fairly among the *N* nodes. However, FDM also shares a principal disad vantage with TDM - a node is limited to a bandwidth of R/N, even when it is the only node with frames to send.

A third channel partitioning protocol is Code Division Multiple Access (CDMA). While TDM and FDM assign times slots and frequencies, respectively, to the nodes, CDMA assigns a different *code* to each node. Each node then uses its unique code to encode the data bits it sends, as discussed below. We'll see that CDMA allows different nodes to transmit simultane ously and yet have their respective receivers correctly receive a sender's encoded data bits (assuming the receiver knows the sender's code) in spite of "interfering"ransmissions by other nodes. CDMA has been used in military systems for some time (due its anti jamming properties) and is now beginning to find widespread civilian use, particularly for use in ireless multiple access channels.

In a CDMA protocol, each bit being sent by the sender is encoded by multiplying the bit by a signal (the code) that changes at a much faster rate (known as the chipping rate) than The original sequence of data bits. Figure 1.9 shows a simple, idealized CDMA oding/decoding c scenario. Suppose that the rate at which original data bits reach the CDMA encoderdefines the unit of time; that is, each original data bit to be transmitted requires one bit-slot time.Let d_i be the value of the data bit for the *i*th bit slot. Each bit slot is further subdivided into *M* mini-slots; in Figure 1.9, *M=8*, although in practice *M* is much larger.

The CDMA code used by the sender consists of a sequence of *M* values, c_m, $m = 1$,...,*M*, each taking a +1 or -1 value. In the example in Figure 1.9, the *M*-bit CDMA code being used by the sender is (1, 1, 1, -1, 1, -1, -1, -1).

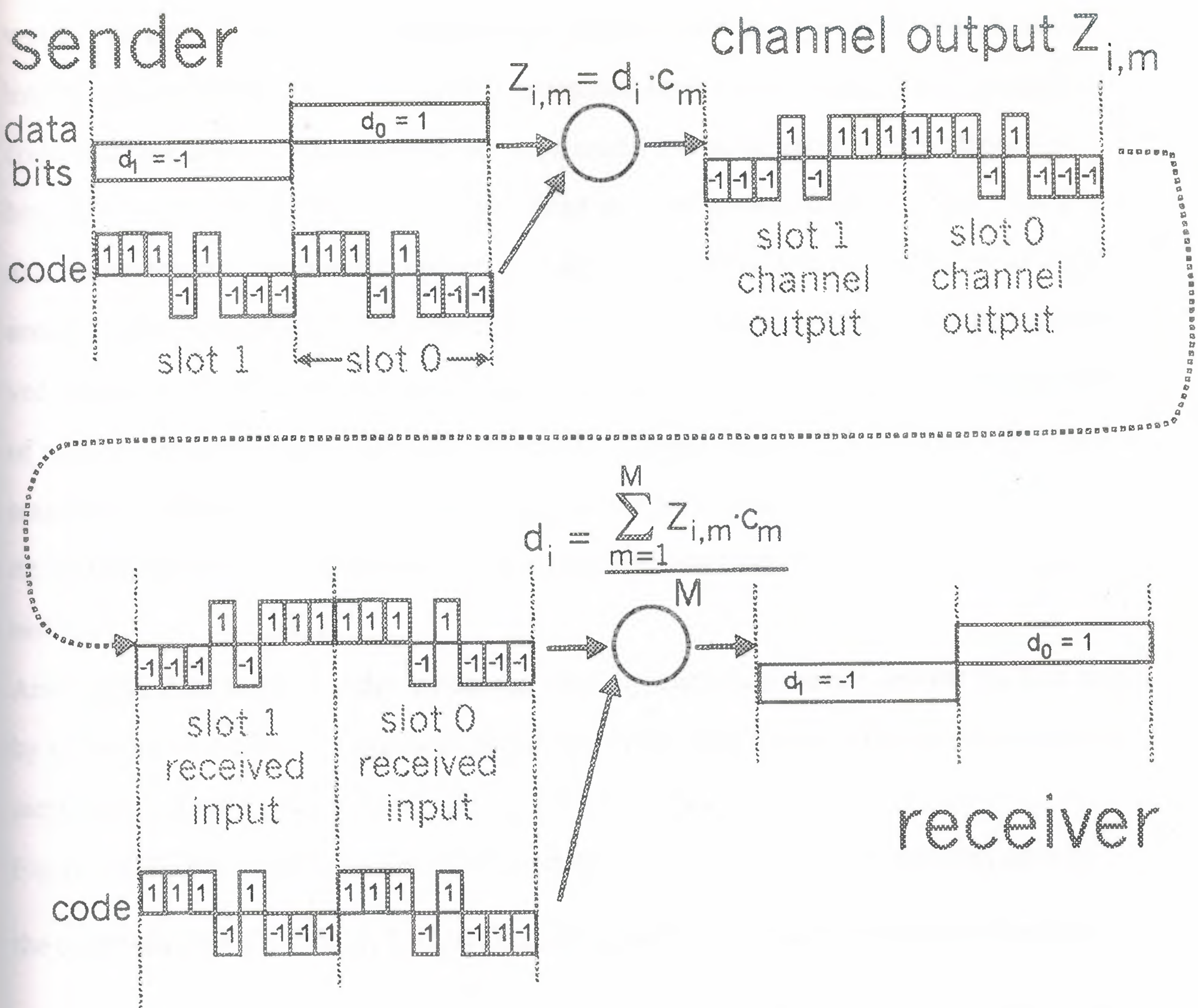


Figure 1.9: A simple CDMA example

This figure shows a simple CDMA example:sender encoding, receiver decoding To illustrate how CDMA works, let us focus on the *i*th data bit, d_i. For the *m*th mini-slot of the bit-transmission time of d_i, the output of the CDMA encoder, $Z_{i,m}$, is the value of d_i multiplied by the *m*th bit in the assigned CDMA code, c_m: $Z_{i,m} = d_i \cdot c_m$ (Equation 1.9-1) In a simple world, with no interfering senders, the receiver would receive the encoded bits, $Z_{i,m}$, and recover the original data bit, d_i, by computing:

$d_i = (1/M) \Box_{m=1,M} Z_{i,m} \cdot c_m$ (Equation 1.9-2)

The reader might want to work through the details of the example in Figure 1.9 to see that the original data bits are indeed correctly recovered at the receiver using Equation 1.9-2 The world is far from ideal, however, and as noted above, CDMA must work in the presence of interfering senders that are encoding and transmitting their data using a different assigned code But how can a CDMA receiver recover a sender's original data bits when those data bits are being tangled with bits being transmitted by other senders. CDMA works under the assumption that the interfering transmitted bit signals are additive, e.g., that if three senders send a 1 value, and a fourth sender sends a -1 value during the same mini-slot, then the received signal at all receivers during hat mini-slot is a 2 (since 1+ 1 + 1 - 1 = 2). In the presence of multiple senders, sender *s* computes its encoded transmissions, $Z_{i,m}^{s}$, in exactly the same manner as in Equation 1.9-1. The value received at a receiver during the *m*th minislot of the *i*th bit slot, however, is now the *sum* of the transmitted bits from all *N* senders during that minislot: $Z_{i,m}^{*} = \sum_{s=1,N} Z_{i,m}^{s}$

Amazingly, if the senders' codes are chosen carefully, each receiver can recover the data sent by a given sender out of the aggregate signal simply by using the sender's code in exactly the same manner as in Equation 1.9-2: $d_i = (1/M) \sum_{m=1,M} Z_{im}^{*} \cdot c_m$ (Equation 1.9-3)

Figure 1.9 illustrates a two-sender CDMA example. The *M*-bit CDMA code being used by the upper sender is (1, 1, 1, -1, 1, -1, -1, -1), while the CDMA code being used by the lower sender is (1, -1, 1, 1, 1, -1, 1, 1). Figure 1.9 illustrates a receiver recovering the original data bits from the upper sender. Note that the receiver is able to extract the data from sender1 in spite of the interfering transmission from sender 2. Returning to our cocktail party ana logy, a CDMA protocol is similar to having partygoers speaking in multiple languages; insuch circumstances humans are actually quite good at locking into the conversation in the lan guage they understand, while filtering out the remaining conversations.

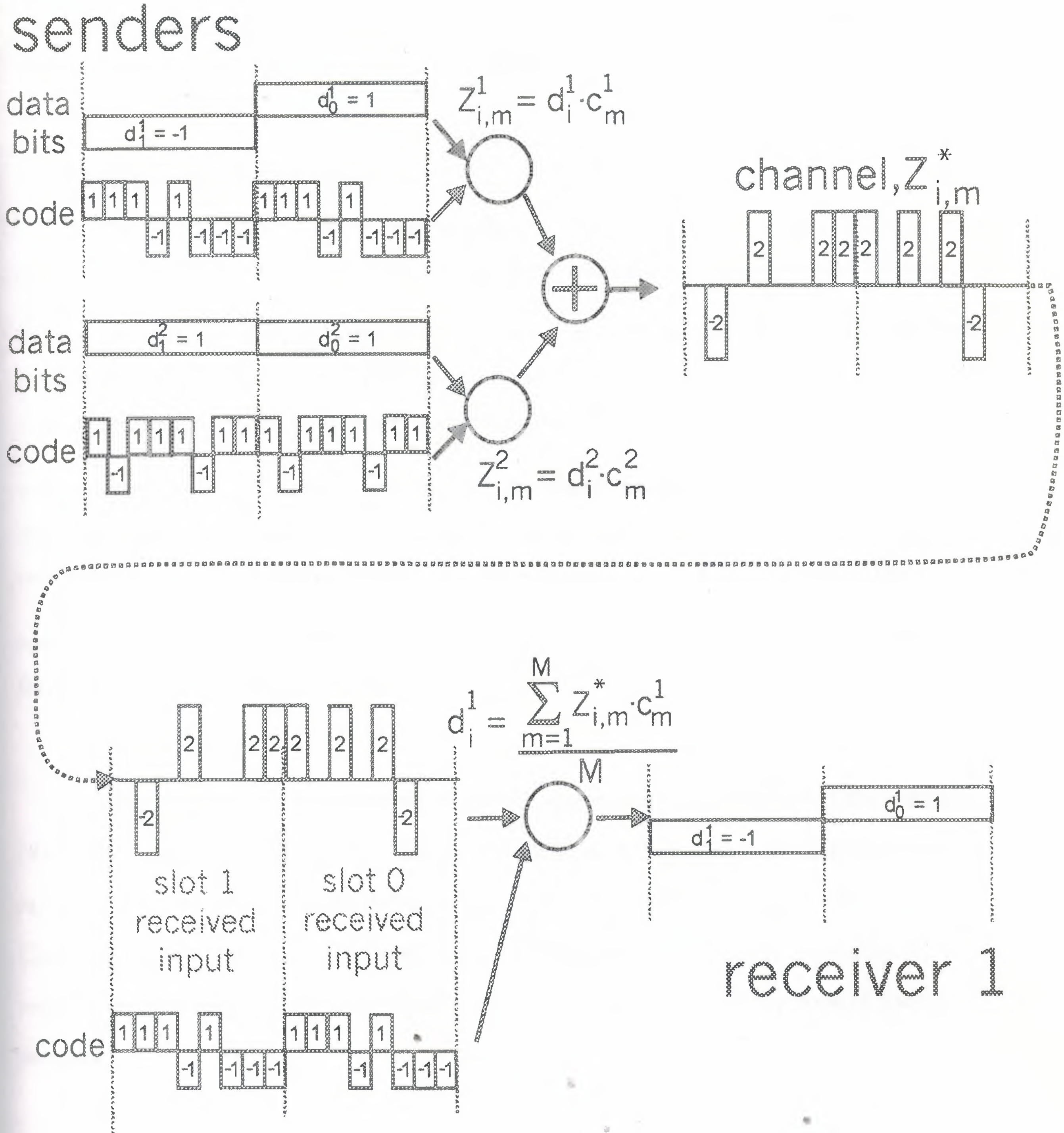


Figure 1.10: A two-sender CDMA example

Our discussion here of CDMA is necessarily brief and a number of difficult issues must be addressed in practice. First, in order for the CDMA receivers to be able to extract out a particular sender's signal, the CDMA codes must be carefully chosen. Secondly, our discussion has assumed that the received signal strengths from various senders at a receiver are the same; this can be difficult to achieve in practice. There is a considerable body of literature addressing these and other issues related to CDMA; see [Pickholtz 1982, Viterbi95] for details.

3.4. RANDOM ACCESS PROTOCOLS

The second broad class of multiple access protocols are so-called random access protocols. In a random access protocol, a transmitting node always transmits at the full rate of the channel, namely, R bps. When there is a collision, each node involved in the collision repeatedly retran smit its frame until the frame gets through without a collision. But when a node experiences a collision, it doesn't necessarily retransmit the frame right away. *Instead it waits a random de- lay before retransmitting the frame*. Each node involved in a collision chooses independent random delays. Because after a collision the random delays are independently chosen, it is possible that one of the nodes will pick a delay that is sufficiently less than the delays of the other colliding nodes, and will therefore be able to "sneak" its frame into the channel without a collision.

There are dozens if not hundreds of random access protocols described in the literature [Rom 1990, Bertsekas 1992]. In this section we'll describe a few of the most commonly used random access protocols - the ALOHA protocols [Abramson 1970, Abramson 1985] and the Carrier Sense Multiple Access (CSMA) protocols [Kleinrock 1975]. Later, in the chapter, we'll cover the details of Ethernet [Metcalfe 1976], a popular and widely deployed CSMA protocol.

CHAPTER 4

4.1. SLOTTED ALOHA

Let's begin our study of random access protocols with one of the most simple random access protocols, the so-called slotted ALOHA protocol. In our description of slotted ALOHA, we assume the following:

- All frames consist of exactly *L* bits.
- Time is divided into slots of size *L/R* seconds (i.e., a slot equals the time to transmit one frame).
- Nodes start to transmit frames only at the beginnings of slots.
- The nodes are synchronized so that each node knows when the slots begin.
- If two or more frames collide in a slot, then all the nodes detect the collision event before the slot ends.

Let *p* be a probability, that is, a number between 0 and 1. The operation of slotted ALOHA in each node is simple:

- When the node has a fresh frame to send, it waits until the beginning of the next slot and transmits the entire frame in the slot.
- If there isn't a collision, the node won't consider retransmitting the frame. (The node can prepare a new frame for transmission, if it has one.)
- If there is a collision, the node detects the collision before the end of the slot. The node retransmits its frame in each subsequent slot with probability *p* until the frame is transmitted without a collision.

By retransmitting with probability *p*, we mean that the node effectively tosses a biased coin; the event heads corresponds to retransmit, which occurs with probability *p*. The event tails corresponds to "skip the slot and toss the coin again in the next slot"; this occurs with probability *(1-p)*. Each of the nodes involved in the collision toss their coins independently.

Slotted ALOHA would appear to have many advantages. Unlike channel partitioning, slotted ALOHA allows a single active node (i.e., a node with a frame to send) to continuously transmit frames at the full rate of the channel. Slotted ALOHA is also highly decentralized, as each node detects collisions and independently decides when to retransmit. (Slotted ALOHA does, however, require the slots to be synchronized in the nodes; we'll shortly discuss anunslotted version of the ALOHA protocol, as well as CSMA protocols; noe of which require suchsynchronization and are therefore fully decentralized.) Slotted ALOHA is also an extremely simple protocol.

Slotted ALOHA also works great when there is only one active node, but how efficient is it when there are multiple active nodes? There are two possible efficiency concerns here. First,as shown in Figure 1.11, when there are multiple active nodes, a certain fraction of the slots will have *collisions* and will therefore be "wasted." The second concern is that another fraction of the slots will be *empty* because all active nodes refrain from transmitting as a result of the probabilistic transmission policy. The only "unwasted" slots will be those in which exactly one node transmits. A slot in which exactly one node transmits is said to be a **successful slot** The **efficiency** of a slotted multiple access protocol is defined to be the long-run fraction of successful slots when there are a large number of active nodes, with each node having a large number of frames to send. Note that if no form of access control were used, and each node were to immediately retransmits after each collision, the efficiency would be zero. Slotted ALOHA clearly increases the efficiency beyond zero, but by how much.

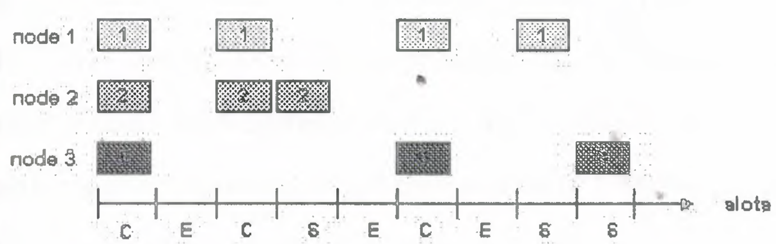


Figure 1.11: Nodes 1, 2 and 3 collide in the first slot

This figure shows nodes 1,2 and 3 collide in the first slot.Node 2 finally succeeds in the fourth slot, node 1 in the eighth slot, and node 3 in the ninth slot.

The notation C, E and S represent "collision slot", "empty slot" and "successful slot", respectively.

We now proceed to outline the derivation of the maximum efficiency of slotted ALOHA. To keep this derivation simple, let's modify the protocol a little and assume that each node attempts to transmit a frame in each slot with probability p. (That is, we assume that each node always has a frame to send and that the node transmits with probability p for a fresh frame as well as for a frame that has already suffered a collision.) Suppose first there are N nodes. Then the the probability that a given slot is a successful slot is the probability that one of the nodes transmits and that the remaining $N-1$ nodes do not transmit. The probability that a given node transmits is p; the probability that the remaining nodes do not transmit is $(1-p)^{N-1}$. Therefore the probability a given node has a success is $p(1-p)^{N-1}$. Because there are N nodes, the probability that an arbitrary node has a success is $Np(1-p)^{N-1}$. Thus, when there are N active nodes, the efficiency of slotted ALOHA is $Np(1-p)^{N-1}$. To obta in the *maximum* efficiency for N active nodes, we have to find the p^* that maximizes this exp- ression. And to obtain the maximum efficiency for a large number of active nodes, we take the limit of $Np^*(1-p^*)^{N-1}$ as N approaches infinity. After performing these calculations, we'll find that the maximum efficiency of the protocol is given by $1/e$ = 37.

That is, when a large number of nodes have many frames to transmit, then (at best) only 37% of the slots do useful work. Thus the effective transmission rate of the channel is not R bps but only .37 R bps! A similar analysis also shows that 37% of the slots go empty and 26% of slots have collisions. Imagine the poor network administrator who has purchased a 100 Mbps slotted ALOHA system, expecting to be able to use the network to transmit data among a lar- ge number of users at an aggregate rate of, say, 80 Mbps! Although the channel is capable of transmitting a given frame at the full channel rate of 100Mbps, in the long term, THA success ful throughput of this channel will be less that 37 Mbps.

4.2. ALOHA

The slotted ALOHA protocol required that all nodes synchronize their transmissions to start at the beginning of a slot. The first ALOHA protocol [Abramson 1970] was actually an unslotted, fully decentralized, protocol. In so-called pure ALOHA, when a frame first arrives (i.e., a network layer datagram is passed down from the network layer at the sending node),the node immediately transmits the frame in its entirely into the broadcast channel. If atransmitted frame experiences a collision with one or more other transmissions, the node will then immediately (after completely transmitting its collided frame) retransmit the frame with probability *p*.Otherwise, the node waits for a frame transmission time. After this wait, it then transmits the frame with probability *p*, or waits (remaining idle) for another frame time.

To determine the maximum efficiency of pure ALOHA, we focus on an individual node. We'll make the same assumptions as in our slotted ALOHA analysis and take the frame transmission time to be the unit of time At any given time, the probability that a node is transmitting a frame is *p*. Suppose this frame begins transmission at time t_0. In order for this frame to be successfully transmitted, no other nodes can begin their transmission in the interval of time $[t_0-1, t_0]$. Such a transmission would overlap with the beginning of the transmission of node *i*'s frame. The probability that all other nodes do not begin a transmission in this interval is $(1-p)^{N-1}$. Similarly, no other node can begin a transmission while node *i* is transmitting, as such a transmission would overlap with the latter part of node *i*'s transmission. The probability that all other nodes do not begin a transmission in this interval is also $(1-p)^{N-1}$. Thus, the probability that a given node has a successful transmission is $p(1-p)^{2(N-1)}$. By taking limits as in the slotted ALOHA case, we find that THA maximum efficiency of the pure ALOHA protocol is only $1/(2e)$ - exactly half that of slotted.ALOHA. This then is the price to be paid for a fully decentralized ALOHA protocol.

4.3. CSMA - CARRIER SENSE MULTIPLE ACCESS

In both slotted and pure ALOHA, a node's decision to transmit is made independently of the activity of the other nodes attached to the broadcast channel. In particular, a node neither pays attention to whether another node happens to be transmitting when it begins to transmit, nor stops transmitting if another node begins to interfere with its transmission. In our cocktail party analogy, ALOHA protocols are quite like a boorish partygoer who continues to chatter away regardless of whether other people are talking. As humans, we have human protocols that allow allows us to not only behave with more civility, but also to decrease the amount of time spent "colliding" with each other in conversation and consequently increasing the amount of amount of data we exchange in our conversations.

Specifically, there are two important rules for polite human conversation:

- *Listen before speaking.* If someone else is speaking, wait until they are done. In the networking world, this is termed **carrier sensing** - a node listens to the channel before transmitting. If a frame from another node is currently being transmitted into the channel, a node then waits ("backs off") a random amount of time and then again senses the channel. If the channel is sensed to be idle, the node then begins frame transmission. Otherwise, the node waits another random amount of time and repeats this process.
- *If someone else begins talking at the same time, stop talking.* In the networking world, this is termed **collision detection** - a transmitting node listens to the channel while it is transmitting. If it detects that another node is transmitting an interfering frame, it stops transmitting and uses some protocol to determine when it should next attempt to transmit.

These two rules are embodied in the family of **CSMA** (Carrier Sense Multiple Access) and **CSMA/CD** (CSMA with Collision Detection) protocols [Kleinrock 1975, Metcalfe 1976, Lam 1980, Rom 1990] . Many variations on CSMA and CSMA/CD have been proposed,with the differences being primarily in the manner in which nodes perform backoff. the reader can consult these references for the details of these protocols. We'll study the CSMA/CD scheme used in Ethernet in detail .Here, we'll consider a few of the most important, and fundamental, characteristics of CSMA and CSMA/CD.The first question that one might ask about CSMA is that if all nodes perform carrier sensing,why do collisions occur in the first place. After all, a node will refrain from transmitting whenever it senses that another node is transmitting. The answer to the question can best be illustrated using space-time diagrams [Molle 1987]. Figure 1.12 shows a space-time diagram of four nodes (A, B, C, D) attached to an linear broadcast bus. The horizontal axis shows the position of each node in space; the y-axis represents time.

At time t_0, node B senses the channel is idle, as no other nodes are currently transmitting.

Node B thus begins transmitting, with its bits propagating in both directions along the broadcast medium. The downward propagation of B's bits in Figure 1.12 with increasing time indicates that a non-zero amount of time is needed for B's bits to actually propagate (albeit at near the speed-of-light) along the broadcast medium. At time t_1 ($t_1 > t_0$), node D has a frame to send. Although node B is currently transmitting at time t_1, the bits being transmitted by B have yet to reach D, and thus D senses the channel idle at t_1. In accordance with the CSMA protocol, D thus begins transmitting its frame. A short time later, B's transmission begins to interfere with D's transmission at D. From Figure1.12, it is evident that the end-to-end channel propagation delay of a broadcast channel - the time it takes for a signal to propagate from one of the the channel to another - will play a crucial role in etermining its performance. The longer this propagation delay, the larger the chance that a carrier-sensing node is not yet able to sense a transmission that has already begun at another node in the network.

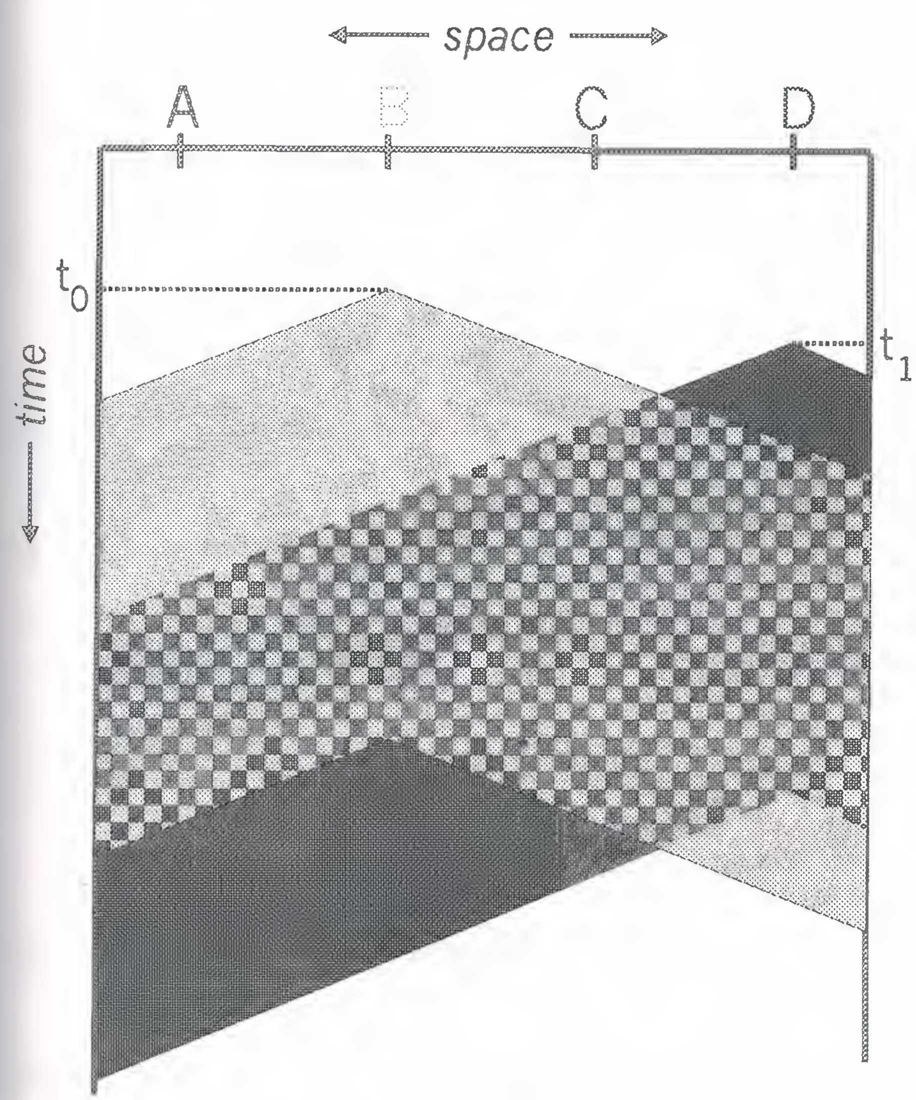


Figure 1.12: Space-time diagram of two CSMA

This figure 1.12 shows Space-Time diagram of two CSMA nodes with colliding

Transmissions.In Figure 1.12, nodes do not perform collision detection; both B and D continue to transmit their frames in their entirety even though a collision has occurred. When a node performs collision detection it will cease transmission as soon as it detects a collision. Figure 1.13 shows the same scenario as in Figure 1.12, except that the two nodes each abort their transmission a short time after detecting a collision. Clearly, adding collision detection to a multiple access protocol will help protocol performance by not transmitting a useless, damaged (by interference with a frame from another node) frame in its entirety. The Ethernet protocol is a CSMA protocol that uses collision detection.

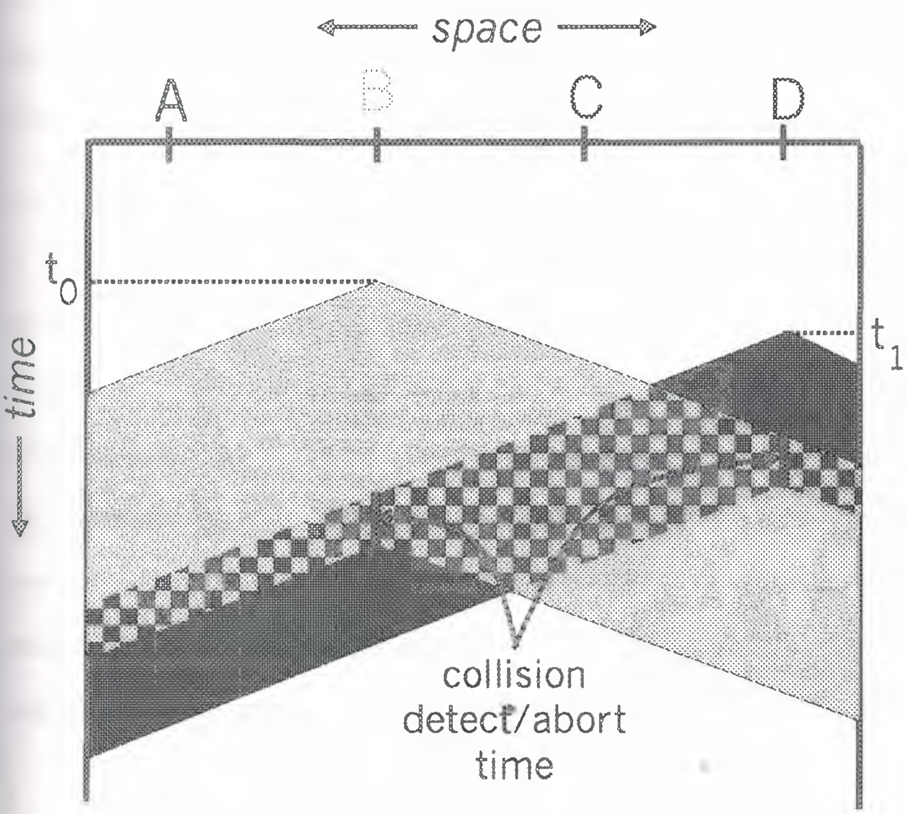


Figure 1.13: CSMA with collision detection

4.4. TAKING-TURNS PROTOCOLS

Recall that two desirable properties of a multiple access protocol are *(i)* when only one node is active, the active node has a throughput of R bps, and *(ii)* when *M* nodes are active, then each active node has a throughput of nearly *R/M* bps. The ALOHA and CSMA protocols have this first property but not the second. This has motivated researchers to create another class of protocols -- the **taking-turns protocols**. As with random-access protocols, there are dozens of taking-turns protocols, and each one of these protocols has many variations. We'll discuss twoof the more important protocols here. The first one is the **polling protocol**. The polling protocol requires one of the nodes to be designated as a "master node" (or requires the introduction of a new node serving as the master). The master node **polls** each of the nodes ina round-robin fashion. In particular, the master node first sends a message to node 1, saying that it can transmit up to some maximum number of frames. After node 1 transmits some frames (from zero up to the maximum number), the master node tells node 2 it can transmit up to the maximum number of frames. (The master node can determine when a node has finished sending its frames by observing the lack of a signal on the channel.) The procedure continues in this manner, with the master node polling each of the nodes in a cyclic manner.

The *polling* protocol eliminates the collisions and the empty slots that plague the random access protocols. This allows it to have a much higher efficiency. But it also has a few drawbacks. The first drawback is that the protocol introduces a polling delay, the amount of time required to notify a node that it can transmit. If, for example, only one node is active, then the node will transmit at a rate less than R bps, as the master node must poll each of the inactive nodes in turn, each time the active node sends its maximum number of frames. The second drawback, which is potentially more serious, is that if the master node fails, the entire channel becomes inoperative.

The second taking-turn protocol is the **token-passing protocol**. In this protocol there is no master node. A small, special-purpose frame known as a **token** is exchanged among the nodesin some fixed order. For example, node 1 might always send the token to node 2, node 2 might always send the token to node 3, node N might always send the token to node 1. When a node receives a token, it holds onto the token only if it has some frames to transmit; otherwise, it immediately forwards the token to the next node. If a node does have frames to transmit when it receives the token, it sends up to a maximum number of frames and then forwards the token to the next node. Token passing is decentralized and has a high efficiency. But it has its problems as well. For example, the failure of one node can crash the entire channel. Or if a node accidentally neglects to release the token, then some recovery procedure must be invoked to get the token back in circulation. Over the years many token-passing products have been developed, and each one had to address these as well as other sticky issues.

CHAPTER 5

5.1. LOCAL AREA NETWORKS

Multiple access protocols are used in conjunction with many different types of broadcast channels. They have been used for satellite and wireless channels, whose nodes transmit over a common frequency spectrum. They are currently used in the upstream channel for cable access to the Internet And they are extensively used in local area networks(LANs).

Recall that a LAN is a computer network that is concentrated in a geographical area, such as in a building or on a university campus. When a user accesses the Internet from a university or corporate campus, the access is almost always by way of a LAN. For this type of Internet access, the user's host is a node on the LAN, and the LAN provides access to the Internet through a router, as shown in Figure. The LAN is a single "link" between each user host and the router; it therefore uses a link-layer protocol, which incorporates a multiple access protocol. The transmission rate, R, of most LANs is very high. Even in the early 1980s, 10 Mbps LANs were common; today, 100 Mbps LANs are common, and 1 Gbps LANs are available.

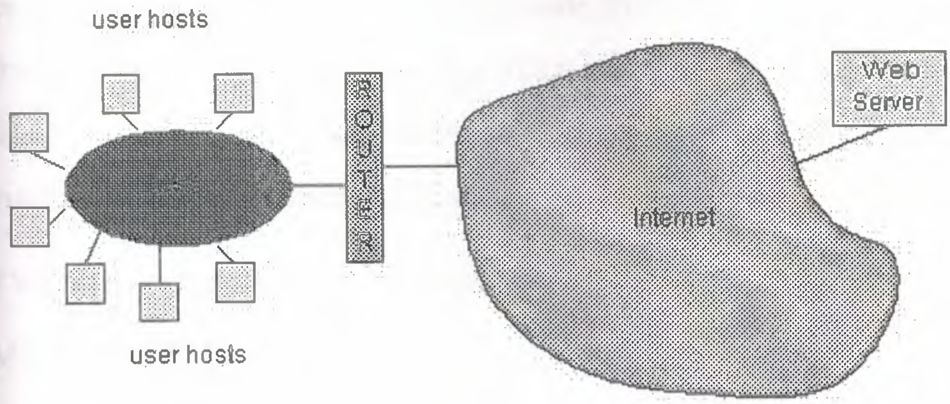


Figure 1.14: User hosts access an Internet Web server through a LAN

The broadcast channel between a user host and the router consists of one "link".

In the 1980s and the early 1990s, two classes of LAN technologies were popular in the workplace. The first class consists of the Ethernet LANs (also known as 802.3 LANs [IEEE 1998b, Spurgeon 1999]), which are random-access based. The second class of LAN technologies are token-passing technologies, including *token ring* (also known as IEEE 802.5 [IEEE 1998]) and *FDDI* (also known as Fiber Distributed Data Interface [Jain 1994]). Because we shall explore the Ethernet technologies in some detail in the next chapter, we focus our discussion here on the token-passing LANs. Our discussion on token-passing technologies is intentionally brief, since these technologies have become relatively minor players in the face of relentless Ethernet competition. Nevertheless, in order to provide examples about token-passing technology and to give a little historical perspective, it is useful to say a few words about token rings.

In a token ring LAN, the *N* nodes of the LAN (hosts and routers) are connected in a ring by direct links. The topology of the token ring defines the token-passing order. When a node obtains the token and sends a frame, the frame propagates around the entire ring, thereby creating a virtual broadcast channel. The node that sends the frame has the responsibility of removing the frame from the ring. FDDI was designed for geographically larger LANs (so called MANs, that is, metropolitan area networks). For geographically large LANs (spread out over several kilometers) it is inefficient to let a frame propagate back to the sending node once the frame has passed the destination node. FDDI has the destination node remove the frame from the ring. (Strictly speaking, FDDI is not a pure broadcast channel, as every node does not receive every transmitted frame.) You can learn more about token ring and FDDI by visiting the 3Com adapter page [3Com].

TWTA - Travelling Wave Tube Amplifier

MPM - Microwave Power Module

5.2.DESCRIPTION

Galileo Avionica provides TWTAs for communications and remote sensing applications.The TWTA for communications applications are designed to operate in CW, Multi-carriers and TDMA modes; Pulsed TWTA are available for remote sensing applications.The TWTA is composed by a TWT (Travelling Wave Tube) and an EPC (Electronic Power Conditioning), physically separated to allow mounting on a dual-temperature controlled payload.

A new power amplifier, dubbed MPM (Microwave Power Module) is now available for Ku- and Ka-bands giving to payload integrators cost and accommodation benefits. The MPM includes all transponder transmit chain in a single box(Channel Amplifier, EPC and TWT).

5.3. TWTA TECHNICAL CHARACTERISTICS

	FTA 02xxx (*)	FTA 04xxx (*)	FTA 08xxx (*)	FTA 12xxx (*)	FTA 20xxx (*)
ng frequency	2400…2700 MHz	3600…4200 MHz	7500…8500 MHz	10700…12750 MHz	19000…22000 MHz
ng band	150 MHz	300 MHz	300 MHz	>500 MHz	>500 MHz
ut power	70…150 W	40…120 W	25…120 W	50…150 W	20…120 W
n	>50 dB	> 45 Db	> 50 dB	>50 dB	>50 dB
cy	> 54%	>55%	> 57%	> 59%	> 58%
us voltage	42, 50, 70 or 100 V regulated; 28 (22…34) or 42 (26…42 V) unregulated				
mmand	ON/OFF; ARU ON/OFF				
try	ON/OFF; ARU enabled/disabled; ARU Status; Anode Voltage; Helix Current; Main Bus Current				
onnector	SMA-F				
Connector	TNC	TNC	WG	WG	WG
ncl. HV cable)	2800 grams	2250 grams	2250 grams	2100 grams	2100 grams
Pressure	Yes				

5.4. SUMMARY OF MILESTONES IN SATELLITE COMMUNICATIONS

1957 Launch of Sputnik 1

1961 Kennedy's policy statement on satellite communications

1962 Launch of TELSTAR1

1962 US Congress enacts Satellite Communications Act

1964 INTELSAT formed

1969 INTELSAT establishes global network

1975 ESA formed

1977 EUTELSAT formed

1979 Inmarsat formed

1979 Ariane's first launch (Highly successful French launch vehicle)

1983 EUTELSAT's first satellite enters service (ECS-1)

1986 Shuttle Challenger Disaster (Regan administration stops launches for one year, backlog of satellites waiting to be launched promotes advances in Delta and Atlas private launch vehicles.

1988 PanAmSat first flight on Maiden Ariane4

1990 Inmarsat launches its own satellites

1995 ICO spun off from Inmarsat

1996 Iridium starts launching its 66 satellite constellation

CHAPTER 6

6.1. CATEGORISATION OF SATELLITES

Satellite categorisation is based upon the type of orbit and area of coverage. When cho osing an orbit for a communications satellite it is generally best to avoid the regions around the earth of intense radiation, the Van Allen belts, where high-energy particles from the sun are entrapped by the Earth's magnetic field. Peaks of radiation occur at altitudes of around 3000-7000km and again at around 13000 - 20000 km where prolonged exposure can seriously shorten the satellites' lifetime. Satellites positioned below the first peak of Van Allen radiation are known as low earth orbit (LEO) satellites and satellites positioned in the gaps between the radiation belts are known as medium earth orbit (MEO) satellites. (Silk and Bath, 1998). In the early years, launch vehicles were unable to lift useful payloads into GEO and so LEO and MEO orbits were used. There are many compelling reasons for using the GEO orbit, such as: the ease with which ground station antenna systems can be deployed and the wide area that a GEO satellite ca see. Thus it is still the orbit of choice for broadcast, major point to point communications, and VSAT communication.

Geostationary Earth Orbit (GEO) satellites orbit the equator at 22,000 miles above the earth and are the furthest away. Three GEOs can cover the entire earth's surface, and are therefore ideal for TV and Radio Broadcasting and international communications.

Middle Earth Orbit (MEO) satellites orbit the earth at 6100 miles, requiring approximately 12 satellites to cover the earth's surface. The lower orbit allows for reduced power requirements and reduced transmission delays.

Low Earth Orbit (LEO) satellites orbit the earth at only 600 miles above sea level, requiring as many as 200 satellites to provide global coverage. Due to their low orbit, these satellites have non-stationary orbits and pass over a stationary caller quickly. Thus requiring them to pass calls on to other satellites as they move out of range. The low level of these satellites means that the Earth based transceivers can be low powered hand held devices, such as the new 'Iridium' satellite mobile phones. (Muller, 1998. P.423) .

Highly Inclined Elliptical Orbit (HEO) satellites can provide polar coverage and high elevation angles at high latitudes while still maintaining some of the advantages of a GEO in that the satellites have little apparent movement as seen by mobile terminals.

6.2. FREQUENCY BANDS

The following tables depict the frequency ranges used in wireless communications and their further sub-allocations for satellite Band communications

High Frequency (HF) 3-30MHz	(Prime Band)
Very High Frequency (VHF) 30-300MHz	(Prime Band)
Ultra High Frequency (UHF) 300-3000MHz	(Prime Band)
Super High Frequency (SHF) 3-30GHz	(Prospective Use)
(Also known as Microwave)	
Extremely High Frequency (EHF) 30-300GHz	(Prospective Use)

(Pelton, 1995. P.17)

6.3. SPECTRUM ALLOCATIONS

L Band: 1.5-1.65 GHz

S Band: 2.4-2.8 GHz

C Band: 3.4-7.0 GHz

X Band: 7.9-9.0 GHz
Ku Band: 10.7-15.0 GHz

Ka Band: 18.0-31.0 GHz

(Elbert, 1997. P.9)

Existing satellite allocations of traditional bands such as C-band (4/6GHz) and Ku-band (11-14 GHz) are already heavily congested. As a result there has been considerable interest in higher frequencies; that is Ka-band (20/30GHz) and more recently V-band (40/50GHz). Higher frequencies not only provide considerable bandwidth, but can employ smaller antennas on the ground and on the satellite. The reason why they have not been used to-date is that they suffer severe propagation impairments in the wet. (Crane R. V. and Rogers D. V. 1998). For this reason, Ka-band is emerging as the spectrum of choice and a significant number of planned Ka band satellites plan to use efficient onboard switching and onboard processing rather than bent pipes (Goyal R. et al. 1999).

6.4. SERVICES SATELLITES CURRENTLY OFFER

The communication services satellites can offer are vast some examples include:

BroadCasting

- Planned global broadcasts of world events, eg World Cup
- Occasional use broadcasting of major news stories
- Distribution of TV channels to headends of Cable network providers
- Business TV
- Direct to home TV distribution
- CD quality radio broadcasts
- Multicasting of Internet Information to may sites

Telecommunications

- International Public switched services to distant country gateways
- Provision of domestic telecommunications where terrstrial infrastructure does not exist
- Private leased line service
- Rapid remote site data distribution
- Extending a LAN over Satellite to remote LANs
- Internation backbone links carrying Internet traffic.

Mobile and Personal Communications

- Voice, Fax, data services to the maritime, areonatautical and land mobility community
- Aeronautical and Maritime distress and safety services
- Vehicle tracking and cargo management
- Wide area paging
- Wide are extension of terrestrial cellular radio
- Differential correction of global positioning satellite navigation transmissions

Rapid Deployment Services

- Early provision prior to terrestrial deployment of infrastructure
- Restoration of Transoceanic cables
- Communications for temporary events
- Emergency Services for remote locations
- Communications to areas disrupted by natural disasters
- Communications to world hot spots

6.5. HOW DOES SATELLITE COMMUNICATION WORK

A satellite uses a radio frequency repeater, providing a relay station between a sender and receiver. Communications satellite systems are made up of; the earth segment, consisting of the equipment at the Hub and at the remote locations, and the space segment, the link to and from the satellite. To communicate via satellite, the sender first converts a signal (radio, TV, data, voice, video) into electronic form. This is transmitted or "up-linked" to the satellite using high powered amplifiers and antennas designed to direct the signal towards the satellite. After travelling 36,000km to the satellite, the transmitted signal is weak and needs to be amplified by a "transponder" located on the satellite. A transponder is a combination of a receiver, frequency converter and transmitter package.

Once the signal has been amplified, and the frequency changed from the up-link frequency (to minimise interference with the up-link), the down-link is sent back to earth. Once the signal reaches the ground it is received by another antenna and amplified before being demultiplexed and sent on to it's many destinations.

6.6. VSAT (VERY SMALL APERTURE TERMINALS) RECEIVE ONLY

Through the use of Very Small Aperture Terminals, satellite companies such as Hughes have released products such as 'Direct PC' allowing internet download to a single PC to occur at speeds starting at 400Kbps. This is achieved by sending search request (outgoing) packets over the conventional public switched network (dial-up modem, ISDN link, etc) and receiving all incoming data through the personal VSAT antenna. The VSAT antenna that is installed on the roof, is directly connected to the PC via an ISA card inserted into the mother board of the machine allowing download speeds of 400kbps to the machine. This method has the following advantages:

- Demonstrable increases in staff efficiency and company cost savings.
- *High* speed transmission for greater use of pictures and video.
- Reception of large files with unmatched speed and efficiency.

- Direct reception from Internet and other major information databases.
- No dedicated facilities such as T1 or ISDN are required to receive Internet information quickly and cost-effectively (assuming use of a dial up connection for sending packet requests).
- Use of the latest in High speed satellite technology.
- Limited capital investment allowing individuals and small businesses access to satellite Technology.
- Windows based applications software provides efficient interface with TCP/IP packages and networks.
- The ISA adapter card can provide: 12Mbps DirectPC signal reception, Secure ASIC based DES decryption to prevent unauthorised access. 128k memory buffer and power to the antenna via coax cable. (Features of DirectPC).
- The antenna dish is 24 inches in diameter and can be mounted in a variety of different positions and is grounded for lightning protection. The installation process is quick taking less then an hour. (AAP Communication Services brochure).

VSAT DAMA (Demand Assigned Multiple Access) networks provide on-demand toll-quality voice, Group III fax and voice-band data together with synchronous and asynchronous data services to remote locations via satellite. This technology maximises the use of available space segment and ground-based resources, providing bandwidth on demand. (AAPT SAT-TEL Company Profile).

CONCLUSION

Although continous evaluation marks the technology and practice of satellitecommuni nication engineering.An engineering always needs the investigation and development about own branch,hence they must be had enough angineering information.

The effects of (multipath) radio propagation, modulation, and coding and signal processing techniques on the spectrum efficiency and performance of wireless radio networks are studied, in particular Orthogonal Frequency Division Multiplexing (OFDM) and related transmission methods.

In a spread spectrum communication system users employ signals which occupy a significantly larger bandwidth than the symbol rate. Such a signalling scheme provides some advantages which are primarily of interest in secure communication systems, e.g., low probability of intercept or robustness to jamming.

Three basic elements can be distinguished in the system:

- the single Network Management Station (NMS) is responsible for the overall management of the network
- the Gateway Hub Earth Stations (GHESs) provides the interface of Eutelsat DSAT
- the Remote Terminals (RTs). Fixed / transportable RTs are foreseen in the EUTELSAT DSAT 160 network.

Slotted ALOHA would appear to have many advantages. Unlike channel partitioning, slotted ALOHA allows a single active node (i.e., a node with a frame to send) to continuously transmit frames at the full rate of the channel.

LAN is a computer network that is concentrated in a geographical area, such as in a building or on a university campus. When a user accesses the Internet from a university or corporate campus, the access is almost always by way of a LAN. For this type of Internet access, the user's host is a node on the LAN, and the LAN provides access to the Internet through a router.

A satellite uses a radio frequency repeater, providing a relay station between a sender and receiver. Communications satellite systems are made up of; the earth segment, consisting of the equipment at the Hub and at the remote locations, and the space segment, the link to and from the satellite.

ABBREVIATIONS

OFDM: Orthogonal Frequency Division Multiplexing

DAB: Digital Audio Broadcasting

CDMA: Carrier Division Multiple Access

MC-CDMA: Multi Carrier –Carrier Division Multiple Access

DS: Direct Sequence

BER: Bit Error Rate

RED: Random Early Discard

CDMA: Code Division Multiple Access

TDMA : Time Division Multiple Access

FDMA: Frequency Division Multiple Access

FFT: Fourier Trans form

DS: Direct Sequence

CDMA: Code Division Multiple Access

MCSS: Multi-Carrier spread-spectrum

CSMA/CD: Carrier Sense Multiple Access/Collision Detect

GSM: Global System Mobile

WCDMA: Wide Band CDMA

EDGE: Enhanced Data GSM E

MF-TDMA: Multi-Frequency Time Division Multiple Access

TDMA : Time Division Multiple Access

DSAT : Digital Satellite

SCPC: Single-Channel-per-Carrier

DAMA : Demand Assigned Multiple Access

PAMA : Pre-Assigned Multiple Access

SSMA: Spread Spectrum Multiple Access

VPNs: Virtual Private Networks

AMPS: Advanced Mobile P System

GHESs: Gateway Hub Earth Stations

RTs : Remote Terminals

NMS: Network Management Station

PSTN: Public Switching Telephone Network

RF: Radio Frequency

MAPs: Multiple Access Protocols

PPP: The Point-to-Point Protocol

LANs: local area networks

TDM: Time Division Multiplexing

FDM: Frequency Division Multiplexing

CSMA : Carrier Sense Multiple Access

CD : Collision Detection

MANs: Metropolitan Area Network

TWTA : Travelling Wave Tube Amplifier

MPM : Microwave Power Module

TWT : Travelling Wave Tube

EPC: Electronic Power Conditioning

MPM : Microwave Power Module

GEO: Geostationary Earth Orbit

LEO: Low Earth Orbit

HEO: Highly Inclined Elliptical Orbit

HF: High Frequency

VHF: Very High Frequency

UHF: Ultra High Frequency

SHF : Super High Frequency

EHF: Extremely High Frequency

ISDN: International Subcriber Digital Network

VSAT : Very Small Aperture Terminals

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