CDMA and ATM - 21.03.2006

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1 CDMA-Code Division Multiple Access

This is a multiplexing technique used with spread spectrum.

For a data signal with rate D, we break it into a pattern of k chips so that the new channel has a data rate of kD chips per second. For a code with k=6, for example, for each user there is a specific code for 1 and its complement (in the complement the 1s and -1s are reversed) for 0.

Suppose user A has c=¡1,-1,-1,1,-1,1¿ , user B has c=¡1,1,-1,-1,1,1¿, user C has c=¡1,1,-1,1,1,-1¿.

Whenever one of these communicates with the base station, it is assumed to know their code. The receiver decodes the chip pattern. Suppose the chip pattern received by the receiver is ¡d1,d2,d3,d4,d5,d6¿ and it wants to communicate with a user u whose code is¡u1,u2,u3,u4,u5,u6¿ then it performs S(d)=d1*c1+d2*c2+d3*c3+d4*c4+d5*c5+d6*c6

If A sends a 1, this becomes 6.

Sa(1,-1,-1,1,-1,1)= 1*1+(-1)*(-1)+(-1)*(-1)+1*1+(-1)*(-1)+1*1

Similarly, if it is a 0 we get -6.

Hence, regardless of values of d, we get for user A, -6 =¡ S ¡= 6

However, we find that if B sends a 1 bit, and we try to receive it using the S for A, then we get a 0, since the code for a 1 in A is multiplied with that of the d value for B. Sa(1,1,-1,-1,1,1)=1*1+1*(-1)+(-1)*(-1)+(-1)*1+1*(-1)+1*1=0

The result would be the same if B were to transmit a 0 as well.

Hence, if the signal is linear, and A and B transmit their respective signals simultaneously, then the decoder ignores B when using A's code. The codes of A and B have the property that Sa(Cb)=Sb(Ca)=0 and are called orthogonal. Such codes are not many in number. It is easier to have codes where Sx(Cy) is small in value and it is easy to say where X=Y and where they are not equal. In the above example, Sa(Cc)=Sc(Ca)=0, but Sb(Cc)=Sc(Cb)=2. Here the C signal would, in fact, make a small contribution to the decoded signal. Thus, using the decoder, the receiver can sort out transmission from u even when there are other users broadcasting in the same cell.

However, if there are too many users competing for the channel which the receiver is trying to listen to, the system may break down.

2 ASYNCHRONOUS TRANSFER MODE

2.1 PROTOCOL ARCHITECTURE:

Asynchronous transfer mode (ATM), also known as cell relay, is in some ways similar to packet switching using X.25 and frame relay. Like packet switching and frame relay, ATM involves the transfer of data in discrete chunks. Also, like packet switching and frame relay, ATM allows multiple logical connections to be multiplexed over a single physical interface. In the case of ATM, the information flow on each logical connection is organized into fixed-size packets, called cells.

ATM is a streamlined protocol with minimal error and flow control capabilities; this reduces the overhead of processing ATM cells and reduces the number of overhead bits required with each cell, thus enabling ATM to operate at high data rates. Further, the use of fixed-size cells simplifies the processing required at each ATM node, again supporting the use of ATM at high data rates.

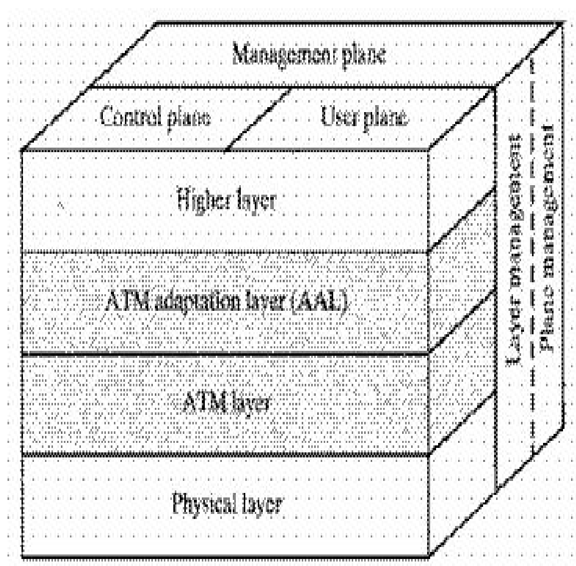

Figure 1: The ATM Protocol Reference Model

The protocol reference model makes reference to three separate planes:

1. User Plane. Provides for user information transfer, along with associated controls (e.g., flow control, error control).

2. Control Plane. Performs call control and connection control functions.

3. Management Plane. Includes plane management, which performs management functions related to a system as a whole and provides coordination between all the planes, and layer management, which performs management functions relating to resources and parameters residing in its protocol entities.

2.2 ATM LOGICAL CONNECTIONS:

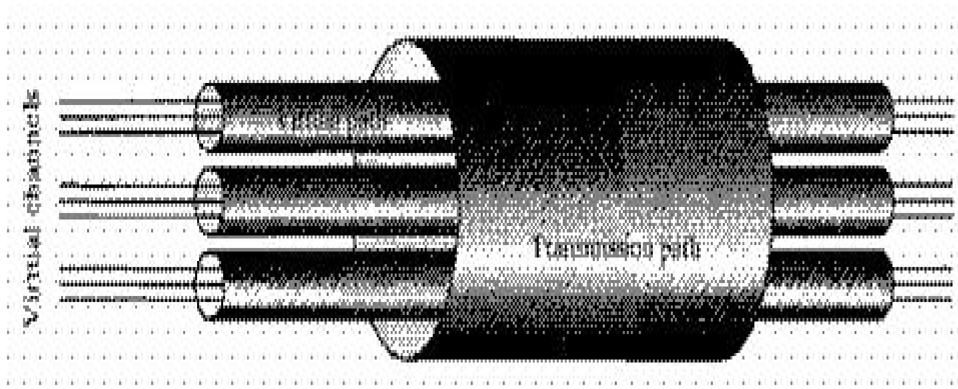

Figure 2: ATM Connection Relationships

Logical connections in ATM are referred to as virtual channel connections (VCC). A VCC is analogous to a virtual circuit in X.25 or a data link connection in frame relay; it is the basic unit of switching in an ATM network. A VCC is set up between two end users through the network and a variable-rate, full-duplex flow of fixed-size cells is exchanged over the connection. VCCs are also used for user-network exchange (control signaling) and network-network exchange (network management and routing).

For ATM, a second sublayer of processing has been introduced that deals with the concept of virtual path (Figure 11.2). A virtual path connection (VPC) is a bundle of VCCs that have the same endpoints. Thus, all of the cells flowing over all of the VCCs in a single VPC are switched together.

Several advantages can be listed for the use of virtual paths:

1. Simplified network architecture. Network transport functions can be separated into those related to an individual logical connection (virtual channel) and those related to a group of logical connections (virtual path).

2. Increased network performance and reliability. The network deals with fewer, aggregated entities.

3. Reduced processing and short connection setup time. Much of the work is done when the virtual path is set up. By reserving capacity on a virtual path connection in anticipation of later call arrivals, new virtual channel connections can be established by executing simple control functions at the endpoints of the virtual path connection; no call processing is required at transit nodes. Thus, the addition of new virtual channels to an existing virtual path involves minimal processing.

4. Enhanced network services. The virtual path is used internal to the network but is also visible to the end user. As a result, the user may define closed user groups or closed networks of virtual-channel bundles.

Figure 3 suggests in a general way the call-establishment process using virtual channels and virtual paths. The process of setting up a virtual path connection is decoupled from the process of setting up an individual virtual channel connection:

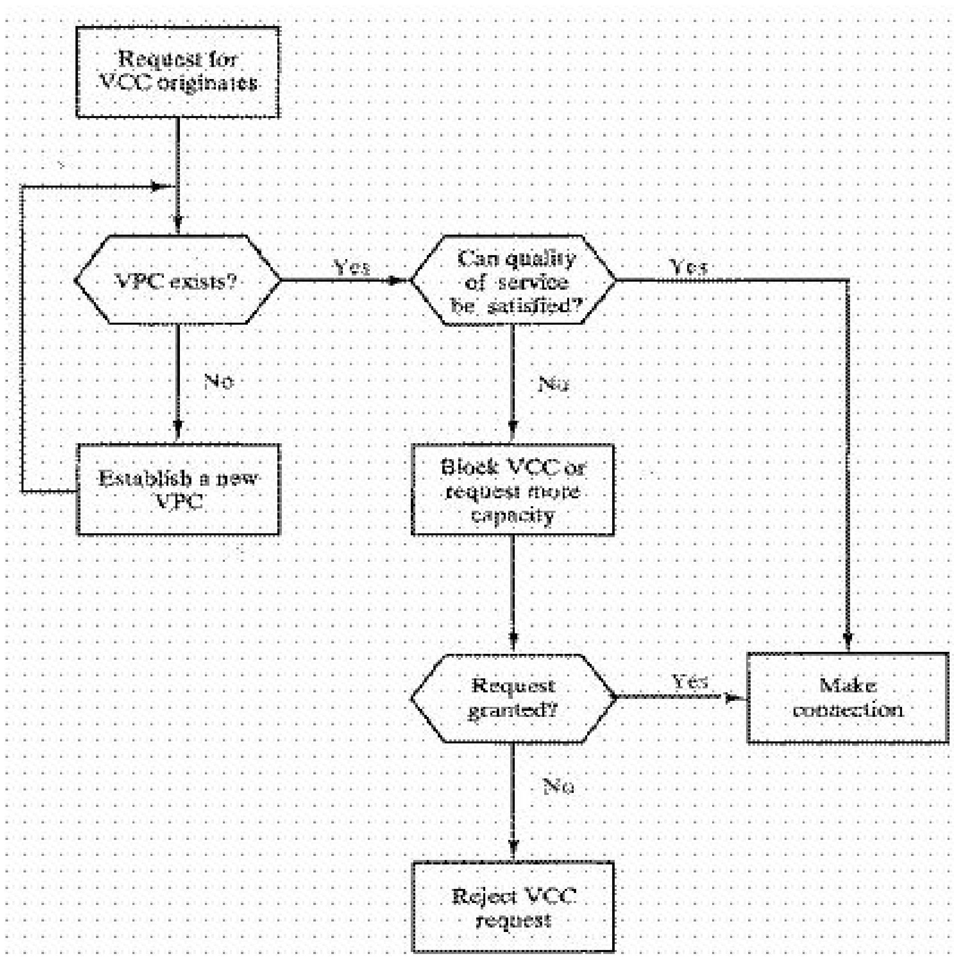

Figure 3: Call Establishment using Virtual Paths

The virtual path control mechanisms include calculating routes, allocating capacity, and storing connection state information.

To set up a virtual channel, there must first be a virtual path connection to the required destination node with sufficient available capacity to support the virtual channel, with the appropriate quality of service. A virtual channel is set up by storing the required state information (virtual channel/virtual path mapping).

2.3 Virtual Channel Connection Uses:

The endpoints of a VCC may be end users, network entities, or an end user and a network entity. In all cases, cell sequence integrity is preserved within a VCC; that is, cells are delivered in the same order in which they are sent. Let us consider examples of the three uses of a VCC.

Between end users. Can be used to carry end-to-end user data; can also be used to carry control signaling between end users, as explained below. A VPC between end users provides them with an overall capacity; the VCC organization of the VPC is up to the two end users, provided the set of VCCs does not exceed the VPC capacity.

Between an end user and a network entity. Used for user-to-network control signaling, as discussed below. A user-to-network VPC can be used to aggregate traffic from an end user to a network exchange or network server.

Between two network entities. Used for network traffic management and routing functions. A network-to-network VPC can be used to define a common route for the exchange of network management information.

2.4 Virtual Path/Virtual Channel Characteristics:

ITU-T Recommendation 1.150 lists the following as characteristics of virtual channel connections: Quality of service. A user of a VCC is provided with a Quality of Service specified by parameters such as cell loss ratio (ratio of cells lost to cells transmitted) and cell delay variation. Switched and semi-pemanent virtual channel connections. Both are switched connections, which require call-control signaling, and dedicated channels can be provided. Cell sequence integrity. The sequence of transmitted cells within a VCC is preserved. Traffic parameter negotiation and usage monitoring. Traffic parameters can be negotiated between a user and the network for each VCC. The input of cells to the VCC is monitored by the network to ensure that the negotiated parameters are not violated.

The types of traffic parameters that can be negotiated include average rate, peak rate, burstiness, and peak duration. The network may need a number of strategies to handle congestion and to manage existing and requested VCCs. At the crudest level, the network may simply deny new requests for VCCs to prevent congestion. Additionally, cells may be discarded if negotiated parameters are violated or if congestion becomes severe. In an extreme situation, existing connections might be terminated. 1.150 also lists characteristics of VPCs. The first four characteristics listed are identical to those for VCCs. The WC characteristics impose a discipline on the choices that the end users may make. In addition, a fifth characteristic is listed for VPCs: Virtual channel identifier restriction within a VPC.

One or more virtual channel identifiers, or numbers, may not be available to the user of the WC, but may be reserved for network use. Examples include VCCs used for network management.

2.5 Control Signalling:

In ATM, a mechanism is needed for the establishment and release of VPCs and VCCs. The exchange of information involved in this process is referred to as control signaling, and takes place on separate connections from those that are being managed. For VCCs, 1.150 specifies four methods for providing an establishment/release facility. One or a combination of these methods will be used in any particular network:

1. Semi-permanent VCCs may be used for user-to-user exchange. In this case, no control signaling is required.

2. If there is no pre-established call control signaling channel, then one must be set up. For that purpose, a control signaling exchange must take place between the user and the network on some channel. Hence, we need a permanent channel, probably of low data rate, that can be used to set up VCCs that can be used for call control. Such a channel is called a meta-signaling channel, as the channel is used to set up signaling channels.

3. The meta-signaling channel can be used to set up a VCC between the user and the network for call control signaling. This user-to-network signaling virtual channel can then be used to set up VCCs to carry user data.

4. The meta-signaling channel can also be used to set up a user-to-user signaling virtual channel. Such a channel must be set up within a pre-established WC. It can then be used to allow the two end users, without network intervention, to establish and release user-to-user VCCs to carry user data.

For VPCs, three methods are defined in 1.150:

1. A VPC can be established on a semi-permanent basis by prior agreement. In this case, no control signaling is required.

2. VPC establishmentlrelease may be customer controlled. In this case, the customer uses a signaling VCC to request the VPC from the network.

3. VPC establishmentlrelease may be network controlled. In this case, the network establishes a VPC for its own convenience. The path may be network-to-network, user-to-network, or user-to-user.

3 ATM CELLS:

The asynchronous transfer mode makes use of fixed-size cells, which consist of a 5-octet header and a 48-octet information field. There are several advantages to the use of small, fixed-size cells. First, their use may reduce queuing delay for a high priority cell, as it waits less if it arrives slightly behind a lower-priority cell that has gained access to a resource (e.g., the transmitter). Secondly, it appears that fixed size cells can be switched more efficiently, which is important for the very high data rates of ATM. With fixed-size cells, it is easier to implement the switching mechanism in hardware.

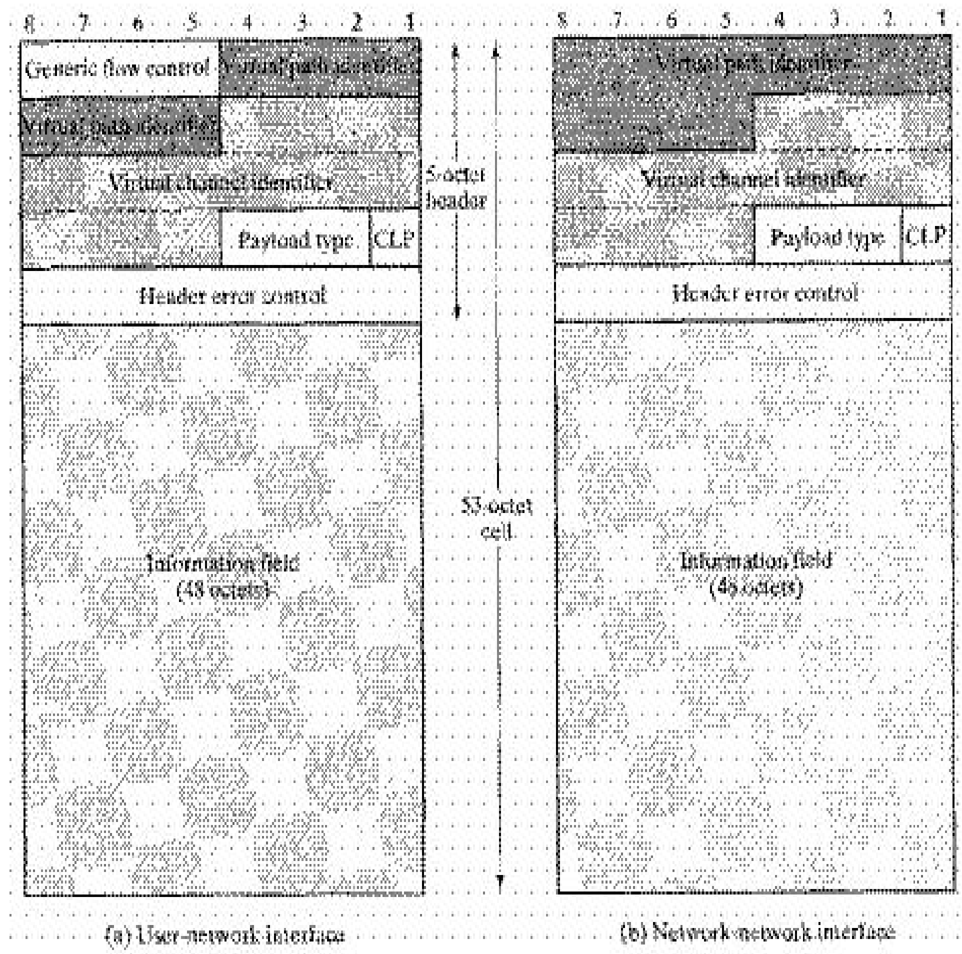

Figure 4: ATM Cell Format

3.1 Header Format:

Figure 5a shows the header format at the user-network interface. Figure 5b shows the cell header format internal to the network, where the generic flow control field, which performs local functions, is not retained. Instead, the virtual path identifier field is expanded from 8 to 12 bits; this allows support for an expanded number of VPCs internal to the network, to include those supporting subscribers and those required for network management.

The generic flow control field does not appear in the cell header internal to the network, but only at the user-network interface. Hence, it can be used for control of cell flow only at the local user-network interface. The details of its application are for further study. The field could be used to assist the customer in controlling the flow of traffic for different qualities of service. One candidate for the use of this field is a multiple-priority level indicator to control the flow of information in a service- dependent manner. In any case, the GFC mechanism is used to alleviate short term overload conditions in the network.

The virtual path identifier (VPI) constitutes a routing field for the network. It is 8 bits at the user-network interface and 12 bits at the network-network interface, allowing for more virtual paths to be supported within the network. The virtual channel identifier (VCI) is used for routing to and from the end user. Thus, it functions much as a service access point.

The payload-type field indicates the type of information in the information field. A value of 0 in the first bit indicates user information-that is, information from the next higher layer. In this case, the second bit indicates whether congestion has been experienced; the third bit, known as the ATM-user-to-ATM-user (AAU) indication bit is a one-bit field that can be used to convey information between end users. A value of 1 in the first bit indicates that this cell carries network management or maintenance information. This indication allows the insertion of network-management cells into a user's VCC without impacting the user's data, thereby providing in-band control information.

The cell-loss priority (CLP) is used to provide guidance to the network in the event of congestion. A value of 0 indicates a cell of relatively higher priority, which should be discarded only when no other alternative is available. A value of 1 indicates that this cell is subject to discard within the network. The user might employ this field so that extra information may be inserted into the network, with a CLP of 1, and delivered to the destination if the network is not congested. The network may set this field to 1 for any data cell that is in violation of an agreement concerning traffic parameters between the user and the network. In this case, the switch that does the setting realizes that the cell exceeds the agreed traffic parameters but that the switch is capable of handling the cell. At a later point in the network, if congestion is encountered, this cell has been marked for discard in preference to cells that fall within agreed traffic limits.

3.2 Header Error Control:

Each ATM cell includes an 8-bit header error control field (HEC) that is calculated based on the remaining 32 bits of the header. The polynomial used to generate the code is X8 + X2 + X + 1. In the case of ATM, the input to the calculation is only 32 bits, compared to 8 bits for the code. The fact that the input is relatively short allows the code to be used not only for error detection but, in some cases, for actual error correction; this is because there is sufficient redundancy in the code to recover from certain error patterns.

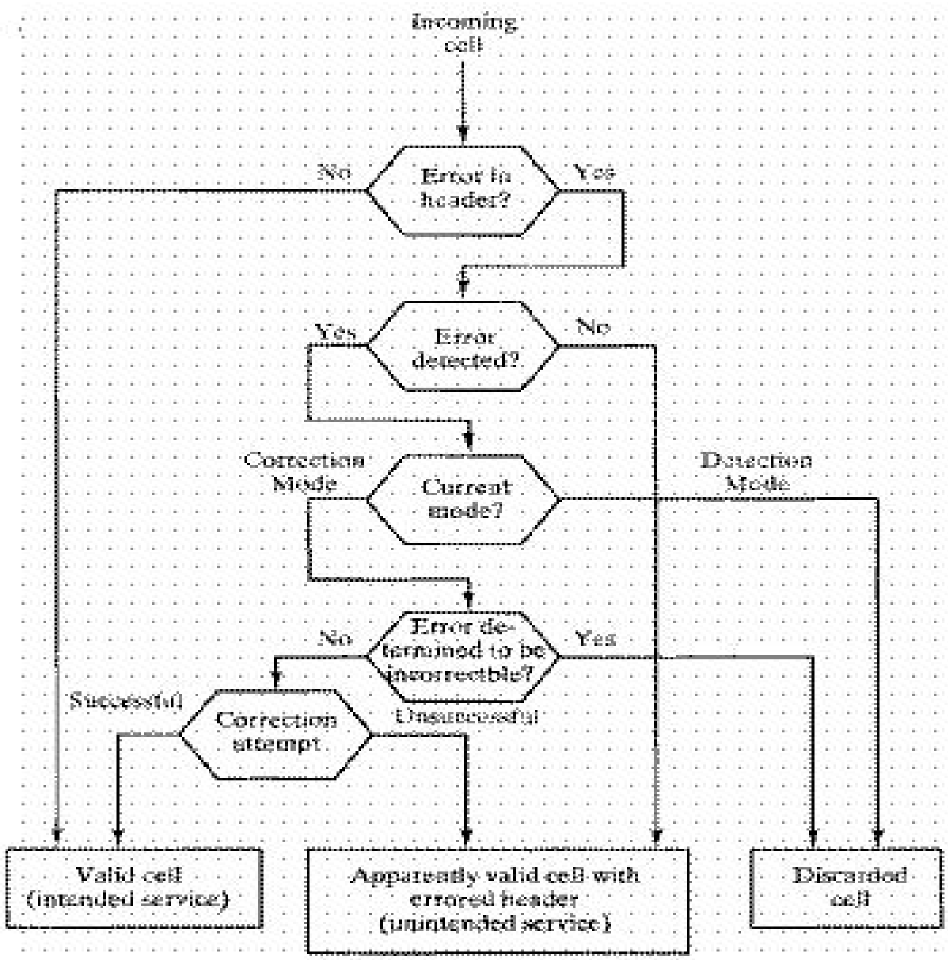

Figure 5: Effect of error in Cell Header

Figure 6 depicts the operation of the HEC algorithm at the receiver. At initialization, the receiver's error-correction algorithm is in the default mode for single-bit error correction. As each cell is received, the HEC calculation and comparison is performed. As long as no errors are detected, the receiver remains in error-correction mode. When an error is detected, the receiver will correct the error if it is a single-bit error or it will detect that a multi-bit error has occurred. In either case, the receiver now moves to detection mode. In this mode, no attempt is made to correct errors. The reason for this change is a recognition that a noise burst or other event might cause a sequence of errors, a condition for which the HEC is insufficient for error correction. The receiver remains in detection mode as long as errored cells are received. When a header is examined and found not to be in error, the receiver switches back to correction mode. The flowchart of Figure 6 shows the consequence of errors in the cell header.

The error-protection function provides both recovery from single-bit header errors, and a low probability of the delivery of cells with errored headers under bursty error conditions.