COMMUNICATIONS PROTOCOLS FOR THE NETWORK AND TRANSPORT LAYERS OF THE AMATEUR PACKET NETWORK

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ABSTRACT

There has been much discussion among amateurs about internetworking with other areas of the country and globe. This has led to the introduction of terms into the vocabulary of many amateurs, many of whom are newly equipped with computers ! In this paper we will present the ISO/CCITT Open Systems concept and its impact on the protocols we will be using to provide reliable data transfer in the amateur network. In order to provide a basis for contrast, we will also introduce the U.S. Department of Defense protocols.

First we will define the basic concepts and terms needed to understand the protocol issues. Once this groundwork is laid, we will explore the protocols needed to provide a reliable data transfer capability. Conclusions will be drawn based upon the experience of the writers and their amateur and professional associates.

TERMS

OS1 -
Open Systems Interconnection Model
The goal of "open systems" is to allow dissimilar computers, networks and terminals to operate together in a common network environment. There are seven layers or functions defined in the model. They provide the basis for interoperability. Standards bodies all over the world have evolved in an unprecedented way to Jointly develop these standards for the telecommunications and computer industries.

Layer -
A functional segment of the OSI model. There are seven.

Physical Layer - level 1
This layer addresses all physical aspects of the communications medium. Voltage, frequency, interface lead assignment and connector layout are all determined by physical layer standards.

Link Layer - level 2
This layer defines the functions of two directly connected points in a network. Link establishment, data transfer, fiow control, error control and term ination are defined.

Network Layer - level 3
This layer defines the means to establish, maintain and terminate network connections through a series of links which compose one or more networks. Link multiplexing, flow control and sequencing of data are also defined in this layer.

Transport Layer - level 4
This layer provides the means to ensure reliable data transfer between end points in the network. Depending on the characteristics of tlhe network layer, different error handling capabilities will be required of the transport layer. The transport layer must be prepared to supply the required reliability if it is unable to obtain a reasonable grade of service from the network layer.

Session Layer - level 5
The session layer is responsible for calling upon the resources required to complete a distributed communications task via a network or networks. A simple session would be a file transfer between two stations in real-time. An example of a more complex session would be a station obtaining needed information from a group of databases in order to locate and properly conduct a series of message transfers with a dispersed group of destinations.

Presentation Layer - level 6
The presentation layer is responsible for code and format conversion between end users. Baudot to ASCII conversion would be the responsibility of this layer.

Application Layer - level 7
This layer defines message formats and procedures used by such applications as electronic mail, bullk file transfer and

remote data processing.

Virtual Circuit - (VC)
A logically-linked path through a network or networks over which data is passed between end users. They usually are setup using call establishment procedures, used for the period of data transfer, then disolved.

Datagramme -
A data unit which contains all neccessary information for routing, error control, sequencing and throughput requirements in addition to the actual user data.

Fast Select -
An X.25 Call Request with 128 bytes of user data.

CCITT -
International Consultive Committee for Telephone and Telegraph. This organization coordinates standards-making activities in the telecommunications field.

IS0 -
The International Organization for Standardization
This body along with the CCITT, formalized the Open System concept and the protocols required to perform the functions of each layer.

X.25 -
A CCITT standard for packet switched network interfaces. It includes recommendations for the first three layers of the IS0 model. AX.25 level 2 was an adaptation of the Link layer of X.25. Level 3 of X.25 provides for a "virtual circuit" to be used as a path for data transfer.

X.224 -
A CCITT standard defining the transport protocol for use in OSI applications.

TPDU - Transport Protocol Data Unit

Internet Protocol -
A datagramme-oriented networking protocol. This level 1 protocol was adopted by the U.S. Department of Defense (DoD) for use on its Advanced Research Project Agency Network (ARPANET),

TCP -
A transport protocol developed by the DoD for ARPANET.
This level 4 protocol was developed to provide end-to-end error recovery in a datagramme-based network.

THE REAL ISSUES

The OS1 model defines peer-level protocols to be used in corresponding communicating entities. The OSI concept separates the issues before us into two ciistinct tasks:

1. The selection of a network layer (level 3) protocol.
   The network layer protocol options are the ISO/CCITT X.25 level 3 and the U.S. DoD Internet Protocol.

2. The selection of a transport layer (level 4) protocol.
   The transport layer options are the ISO/CCITT X.224 and the U.S. DoD Transmission Control Protocol (TCP).

Diagramme 1 shows where these protocols fit in the OSI scheme of things.

THE NETWORK LAYER

The first area of *concern is* the dissimilar way these protocols pass data through a network. The X.25 level 3 protocol has three phases: call set-up, data transfer and call release. A station sets up a path over which data is passed, then transfers the data. The protocol exchange for a virtual circuit (VC) based data transfer would be as shown below.

The DoD Internet Protocol uses datagrammes to provide the needed control to route the packets through the network. There is *no* '@connection" between network the sender and receiver of the the network layer data. Upper layers provide this, leaving the network layer with the tasks of routing. As we will see, this puts a large burden on the end-users of the network and limits throughput by increasing overhead.

The basic issues in deciding between the ISO/CCITT X.25 level 3 and U.S. DoD Internet Protocol are:

1. Protocol Efficiency;
2. Reliability;
3. Ease of Implementation;
4. Interoperability with Non-Amateur Networks:
5. International Acceptance.

1. Protocol Efficiency

The set-up or call establishment procedure allows all stations involved in the call to negotiate the parameters needed to transfer the data over the VC. This is accomplished through the Call Request and Call Accept exchange. It also identifies the end points to all stations involved so that each packet exchanged with user data need only contain a logical identifier. Each station supporting the call must maintain a table entry reflecting the path through the station itself and the current state of that call.

During call establishment, parameters are exchanged which govern the data flow of that call. Some of these parameters are outlined below:

Packet Window Size -
Lets each station know how many unacknowledged packets may be outstanding before an acknowledgement is required.

Packet Size -
Determines the amount of data in each packet. It must be set to a power of two <e.g. 128/256/512/1024 etc.),

Throughput Class -
An indication of the required level service needed to support the call.

Extended Address -
A way to indicate the actual stations *in* the source and destination networks using the locally defined address (e.g. W2VY-5).

The exchange in diagramme 2 shows end-to-end significance to the packet sequence numbers, but at the option of the network it may be locally acknowledged. The Call Request and Accept packets may also contain up to 128 bytes of user data.

Datagrammes contain source and destination addresses, service type, and time-to-live information in each packet. This information is used by the packet switches to route, and if necessary discard, the packet. Most packet switches in commercial networks require 8-15 times the CPU resources to handle routing functions than they do for simple data transfer across an estblished path.

The datagramme approach allows for data units to be sent over random paths causing them to often arrive out of sequence. This is done to increase reliability in the network, but such a measure is unneccessary and forces the transport layer to handle sequence management, complicating the functions of the end user terminals.

The ammount of overhead in the Internet Header is extensive when compared to that of the X.25 level 3 header. There are two cases which require examination:

1. Datagramme vs. Fast Select Packet
2. Datagramme vs. Data Packet.

An X.25 Fast Select call is a normal X.25 call with up to 128 bytes of user data included. It may be acknowledged with either an accept or a clear with up to 128 bytes of user data. In either case it mirrors the function of the datagramme protocol by creating independent data units while at the same time allowing for VC-based exchanges using the same protocol sequence and network.

An IP datagramme will usually contain 20 bytes of overhead in each packet.

The X.25 Fast Select Call Packet will typically contain twenty-four (24) bytes of overhead.

The X.25 Data Packet will contain three (3) bytes of overhead.

The format of a typical Fast Select packet would be as shown below.

X.25 Call Request

GFI	LCGN
LCN	
Packet Type - Call Request	
Calling Length	Called Length
Called Address	
Calling Addre.ss	
Facilities Length	
Facilities	
User Data up to 128 bytes	

Data packets exchanged after the call is established use the format found in diagramme 4.

The format of a typical datagramme packet would be as shown below.

Internet Protocol Datagramme

```
-------------------------------------
|   Version        |      IHL       |
-------------------------------------
|         Type of Service           |
-------------------------------------
|         Total Length              |
-------------------------------------
|         Total Length  (cont.)     |
-------------------------------------
|              ID                   |
-------------------------------------
|              ID (cont.)           |
-------------------------------------
|   Flag          | Fragment Offset |
----L-------------l------------------
| Fragment Offset (cont.)           |
---I---------------------------------
|             Time                  |
-------------------------------------
|            Protocol               |
----------I--------------------------
|    Header Checksum                |
-------------------------------------
|    Header Checksum (cont.)        |
-------------------------------------
|        Source Address             |
-----a-------------------------------
|        Source Address (cont.)     |
-------------------------------------
|        Source Address (cont.1     |
L---11111----------------------------
|        Source Address (cont.)     |
-------------------------------------
|        Destination  Address       |
----I--------------------------------
|        Destination Address (cont.) I
L-III-I------------------------------
|        Destination Address (cont.1 |
----II------C------------------------
|        Destination Address (cont.) |
-----------------I-------------------
|        Options                    |
\                                   \
|                                   |
-------------------------------------
|   Data                            |
\                                   \
|                                   |
-------------------------------------
```

2. Reliability

Packet lengths as noted in the previous section are an important factor in reliability. If the packet is longer, it is more likely to experience errors in transmission.

The data transfer procedures in X.25 level 3 provide for properly sequenced data packets exchanged in a flow controlled-manner between end points. The sequencing of data in the network layer also allows Us to eliminate the error recovery *baggage* needed in the transport layer to resequence the packets. This is a further shortening of the overhead obtained by the VC approach.

Another frequently heard cry is "What happens if a switch goes down ?" In any network there would be a timeout followed by an error recovery procedure. In the case of a datagramme network there would be a new datagramme sent. In the case of *an* X.25 network there would be Clear from the stations adjacent to the one in trouble. This would be followed by a Fast Select Call Packet. Since a definitive action has occurred, the network can decide how subsequent calls should be handled. The clearing cause and diagnostic codes provide the network status information. This information should be used to guide subsequent calls through the network.

3. Ease of Implementation

It is often suggested that it is "too much" to expect that a station or packet switch maintain tables of active virtual circuits passing through. I think we can trust our small (and someday large> switches to maintain tables of call status.

Programming an implementation of the network layer is only a step more difficult than the link layer of AX.25 Level 2. As a point of interest, Phil Karn's (KA9Q) implementation in the C language supports multiple logical links across one or more physical ports. The programming techniques needed at the network layer are almost identical to his approach to the link layer.

4. Interoperability with Non-Amateur Networks

The ability to use the same network layer procedures through interfaces between amateur and non-amateur networks would greatly simplify and expedite completion of such facilities. These interfaces would provide the data equivalent of autopatch and reverse patch. The advantage of the data system over traditional voice telephone autopatches is the presence of the computer gear to validate authorized ham access to the facility. This will go *a* long way toward keeping the FCC happy about amateur control of a non-amateur access.

The addressing format of X.121 IS usually found in X.25. It defines formats for accessing the telephone and telex networks from packet switched networks.

The X.25 protocol has source and destination address facilities which allows for address conventions to be network or user specified. There is no addressing format in IP. The format and actual addresses allowed under TCP are assigned in groups of binary numbers. These have little or no logical relationship to the world an amateur is accustomed.

5. International Acceptance

The X.25 network layer has been impiemented in nearly every country. It is recognized and understood by most regulatory authorities and therefore lends itself to acceptance by those authorities for use in the amateur service. The U.S. DoD (remember: Department of Defense) may not be a big seller in other countries when a recognized international protocol is available.

We in the United States have witnessed the impact we've had on packet radio worldwide. We must keep in mind the needs of amateurs abroad. Their cooperation is needed to provide transit network connections and uniform end-user protocols.

THE TRANSPORT LAYER

The transport protocol options before the amateur community are ISO/CCITT X.224 and the U.S. DoD Transmission Control Protocol (TCP). Unlike their network layer cousins, these protocols have many similarities.

During the late 1960's and 1970's the U.S. Department of Defense (DOD) required networking standards for its own Advanced Research Projects Agency Network (ARPANET). At this time the international standardization effort was just being to be envisioned and no formal acitvity had commenced. The DoD developed a set of protocols for use on ARPANET.

During the last two study periods, the CCITT and IS0 have developed the needed standards. The need for proprietary protocols for general network applications is no longer Justified or constructive for cost effective network development. X.224 provides for a range of network error recovery situations. It is divided into classes of operation. For this discussion we will address class 1.

Class 1 is for use in networks with low undetected error rate, but having high rates of signaled failures. An amateur packet network using X.25 level 3 would certainly fall into this catagory. A packet network with IP as a level 3 protocol would require X.224 class 4 or TCP to provide the needed error control.

The transport layer provides for several functions in the OSI model. They are:

1. End-to-end data integrity;
2. Network connection re-establishment:
3. Re-synchronization after network layer reset.

The same criteria used in evaluating network layer protocols will be used to help us through the transport layer. They are:

1. Protocol Efficiency;
2. Reliability:
3. Ease of Implementation;
4. Interoperability with non-Amateur Networks;
5. International Acceptance.

1. Protocol Efficiency

The TCP and x.224 protocols are functionally similar, however X.224 is leaner and is better suited to the needs of the amateur network. By "leaner" we mean that it uses fewer bytes in its control header, thereby reducing the chance of error on the radio channel.

The X.224 CR TPDU will usually contain 7 bytes of overhead.

The X.224 DT TPDU will have 3 bytes of overhead.

A TCP message will usually have 20 bytes of overhead.

Again we have a situation where the set-up in the CCITT/ISO protocol uses a longer header during the establishment phase in order to gain economies during data transfer. The X.224 class 1 connection request format is as shown below.

X.224 Connection Request

```
-------------------------------------
|          Length Indicator         |
-------------------------------------
| TPDU - CR        |      CDT       |
-------------------------------------
| Destination Reference             |
-------------------------------------
| Destination Reference (cont.)     |
-------------------------------------
| Source Reference                  |
-------------------------------------
| Source Reference (cont.1          |
-------------------------------------
| Class/Options                     |
-------------------------------------
|             User Data             |
\                                   \
|                                   |
-------------------------------------
```

X.224 class 1 operation uses the following format for data transfer:

X.224 Data Transfer

```
-------------------------------------
|        Length  Indicator          |
-------------------------------------
|        TPDU - DT                  |
-------------------------------------
|        Number  Received           |
-------------------------------------
|              User  Data           |
\                                   \
|                                   |
-------------------------------------
```

The format of a typical TCP message would be as shown below.

TCP Message

```
-------------------------------------
|    Source  Port                   |
-------------------------------------
|    Source  Port  (cont.1          |
-------------------------------------
|    Destination  Port              |
-------------------------------------
|    Destination  Port  (cont.)     |
-------------------------------------
|    Sequence  Number               |
-------------------------------------
|    Sequence  Number  (cont.)      |
-------------------------------------
|    Sequence  Number  (cont.)      |
-------------------------------------
|    Sequence  Number  (cont.)      |
-------------------------------------
|    Acknowledgement  Number        |
-------------------------------------
|    Acknowledgement  Number  (cont.) |
-------------------------------------
|    Acknowledgement  Number  (cont.) |
-------------------------------------
|    Acknowledgement  Number  (cont.) |
------------I------------------------
|  Data  Offset  |  Reserved        |
-------------------------------------
| Reserved       |  Control  Bits   |
-------------------------------------
|             Window                |
-------------------------------------
|             Window  (cont.)       |
-------------------------------------
|             Checksum              |
-------------------------------------
|             Checksum  (cont.)     |
-------------------------------------
|          Urgent  Pointer          |
-------------------------------------
|          Urgent  Pointer  (cont.1 |
-------------------------------------
|          Options                  |
\                                   \
|                                   |
-------------------------------------
|   Data                            |
\                                   \
|                                   |
-------------------------------------
```

2. Reliability

Both protocols are deemed reliable for amateur service. It should be noted however, that TCP has a much larger overhead. Any additional functions in TCP that are not used in X.224 class 1 operation are just not needed given a VC-based network.

3. Ease of Implementation

Implementation of either protocol would require the same general tasks. There are fewer implementations of X.224 at this time but this will change. I know of several completed implementations and many more are under development; It is projected to be more widespread than TCP sometime during the 1986-87 time-frame.

4. Interoperability with Non-Amateur Networks

There are implementations of TCP in most Unix systems. Implementations of X.224 are increasing in popularity. Even in the U.S. DoD the CCITT/OSI protocols are attaining new-found recognition. In the February, 1985 issue of Data Communications Magazine, Jerrold S. Foley wrote:

"The U.S. Department of Defense (DOD) has been reviewing OSI protocols for suitability to its requirements. Since both the DOD TCP <transport control protocol> and the OSI transport protocol have strong ties to the Defense Advanced Research Projects Agency, the prospect of interoperability or REPLACEMENT (caps author) of TCP is good. The North Atlantic Treaty Organization has indicated that OSI is central to its data communications planning."

That is certainly interesting food for thought...

5. International Acceptance

TCP is being used world-wide on the ARPANET and in Unix mail applications, but X.224 is being used to support a great number of videotext terminals around the world. There are other classes of operation available within X.224. They can be used with little change to the end user software if the need arises. One such application would be multiplexing many transport connections onto a single network connection. In this case the use of X.224 class 3 would be in order.

SUMMARY

Overall, the protocols available from the CCITT/ISO seem superior to those in the DoD arsenal. The following characteristics stand out:

1. Header Length
   In data transfer, the header length of a TCP/IP packet is at least 40 bytes. The header length in a X.25 level 31X.224 class 1 packet is 7 bytes.

2. Data Parsing in Packet Switches
   The TCP/IP header must be examined by each station in the path to ensure proper handling and routing. This increases switch overhead by 8-15 times above that of the vc switch.

3. U.S. DOD or CCITT/ISO
   NATO and the U.S. DoD have made statements of direction leading to the replacement of TCP with CCITT/ISO protocols on the ARPANET and the Defense Data Network (DDN).

4. Virtual Circuit vs. Datagramme
   No commercial network offers datagrammes. Datagrammes were dropped from X.25 during the 1984 study period,

5. Who has the knowledge to implement a VC based switch ?
   Existing amateur packet implementations have more than demonstrated the availability of programming talent capable of implementing a VC-based packet switch.

6. Packet Voice
   Packet voice has been successfully implemented over virtual circuit networks. The need to transmit data over a network in a short period of time is well handled by CCITT/ISO protocols. The British Telecom network and Japan's KDD have throughput class implemented as a standard offering and GTE Telenet will be Providing voice packet service in late 1985.

7. Interconnection with Public Data and Telephone Networks
   National and international interconnections to public telephone, data and telex services will greatly depend upon the use of internationally recognized protocols.

8. Excess Protocol Baggage
   TCP offers error recovery from problems which we should not have if we use a VC-based network protocol. The same error recovery is available from X.224, but is not a required function of all implementations.

CONCLUSION

Let us understand that the marketplace has already made a stand which is driving the packet switching industry, user community and the standards bodies. Commercial and private packet switched networks are overwhelmingly using Virtual Circuit (VC) based protocols, not datagrammes. This is not to say that the amateur community is bound to follow commercial standards, but it certainly tilts the scales a bit, The Radio Amateur Telecommunications Society wishes to continue in the direction of CCITT/ISO protocols. This direction was started over three years ago in Joint meetings with the Amateur Radio Developement Corporation. These meetings culminated in the ARRL's adoption of AX.25 Level 2 as the amateur link protocol. This standard has done mugch to stimulate and direct packet radio activities to the more complex issues described in this paper and others in the procedings. We hope that the combined efforts of the amateur community will continue to yield great results in the future.

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OFFER

In keeping with its active support of CCITT/ISO protocols, the Radio Amateur Telecommunications Society (RATS) will send to interested parties copies of the protocol documents listed below. Call or write to make arrangements. RATS reserves the right to withdraw this offer at any time without notice.

X.25 - Packet Switched Network Interface Specification

X.200- Reference model of Open Systems Interconnection for CCITT applications

X.210- OSI layer service definition conventions

X.213- Network service definition for Open Systems Interconnection for CCITT applications

X.214- Transport service definition for Open Systems Interconnection for CCITT applications

X.215 Session service definition for Open Systems Interconnection for CCITT applications

X.224- Transport protocol specification Open Systems Interconnection for CCITT applications

X.225- Session protocol specification Open Systems Interconnection *for* CCITT applications

X.2440 Procedure for the exchange of protocol identification during virtual call establishment on packet switched public data networks

X.250- Formal description techniques for data communications protocols and services.

Diagramme 1

OPEN SYSTEM INTERCONNECTION REFERENCE MODEL

```
Level     END USER A                                   END USER B
          ----------------                             ----------------
  7       | Application  |   <------------------->     | Application  |
          ----------------                             ----------------
  6       I Presentation |   <------------------->     | Presentation |
          ----------------                             -----W-W--------
  5       | Session      |   <------------------->     t Session      |
          ----------------                             ----------------
  4       | * TRANSPORT *I   <------------------->     | * TRANSPORT *|
          ----------------                             ----------------
  3       | *  NETWORK * |   <------------------->     | *  NETWORK * |
          ----------------                             ----------------
  2       | Link         |   <------------------->     | Link         |
          ----------------                             ----------------
  1       I Physical     |   <------------------->     I Physical     |
          ----------------                             -----------I----
```

Diagramme 2

Protocol Exchange: X.25 Level 3

Source	Station A	Station B	Destination
Call -->			
	Call -->		
		Call -->	
			Call -->
			<-- Accept
		<-- Accept	
	<-- Accept		
<-- Accept			
Data 0 -->			
Data 1 -->	Data 0 -->		
	Data 1 -->	Data 0 -->	
		Data 1 -->	Data 0 -->
			<-- RR 0
		<-- RR 0	Data 1 -->
Data 2 -->	<-- RR 0		
<-- RR 0	Data 2 -->		
		Data 2 -->	
			Data 2 -->
			<-- RR 2
		<-- RR 2	
Data 3 -->	<-- RR 2		
<-- RR 2		Data 3 -->	
			Data 3 -->
			<-- RR 3
		<-- RR 3	
	<-- RR 3		
<-- RR 3			
Clear -->			
	Clear -->		
		Clear -->	
			Clear -->
			<-- Clr Cfm
		<-- Clr Cfm	
	<-- Clr Cfm		
<-- Clr Cfm			

Diagramme 3
--------- -

```
                 Protocol Exchange:  Internet Protocol
                 -------- ---------  -------- --------

Source      Station A    Station C   Station B      Destination
----------------------------------------------------------------
Data 0 -->
Data 1 -->     Data 0 -->
               Data 1 --------------------->
                         Data 0 -->
                                   Data 0 -->       Data 1 -->
                                                    Data 0 -->
                                                    <-- ACK 0
                                   <-- ACK 0
                         <-- ACK O
               <-- ACK 0
<-- ACK 0
Data 2 -->
               Data 2 -->
                         Data 2 -->
                                   Data 2 -->
                                                    Data 2 -->
                                                    <-- ACK 2
                                   <-- ACK 2
                         <-- ACK 2
              <-- ACK 2
<-- ACK 2
```

Diagramme 4
--------- -

```
                         X.25 Data Packet
                         ---- ---- ------

              -------------------------------------
              |      GFI        |      LCGN       |
              -------------------------------------
              |                LCN                |
              -------------------------------------
              |        Packet Type - Data         |
              -------------------------------------
              |             User Data             |
              \                                   \
              |      up to 256 bytes (default)    |
              -------------------------------------
```

PROPOSAL: RECOMMENDATION AX.121NA

NUMBERING PLAN FOR THE AMATEUR RADIO NETWORK IN NORTH AMERICA

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Introduction

The purpose of this Numbering Plan is to facilitate the introduction of amateur data networks and provide for internetworking in the North American region.

1.0 Design Considerations

1.1 This proposal does not require, nor preclude, governmental involvement in network administration.

1.2 The Regional Numbering Plan should permit the identification of a called country as well as a specific network and station.

1.3 The Numbering Plan should provide a consistent addressing format when connection is made with or through commercial telephone networks.(i.e. telephone, telex, data networks.)

1.4 A national number assigned to a terminal should be unique within a particular network. This national number should form part of the international number which should also be unique on a worldwide basis.

1.5 Specific national numbers should be easily determined.

1.6 National Numbers shouid require minimal administrative overhead to network management and users.

2.0 Numbering System

2.1 The 10 digit numeric character set O-9 should be used for numbers (or addresses> assigned to terminals in the amateur network. This principle should apply to both national and international numbers.

2.2 Use of the numbering system as outlined in 2.1 will make it possible to interwork with terminals on public telephone, telex and data networks.

3.0 Prefix Codes

3.1 The Prefix Code will signify the type of network indicated by the remaining digits.

3.2 The Prefix Code will be the first digit and should be coded as follows:

```
0     Amateur Packet Switched Network
1     Public Packet Switched Network
2     \
3      \
4       \___ Reserved
5       /
6      /
7     /
8     Telex Network
9     Telephone
```

4.0 Data Network Identification Codes

4.1 All Data Network Identification Codes shall consist of four digits.

4.2 Each country in the region shall use the codes listed below.

3020	Canada
3100	United States of America
3300	Puerto Rico
3320	Virgin Islands (USA)
3340	Mexico

5.0 National Number

5.1 The National Number shall consist of up to 10 digits.

5.2 Each National Number shall be unique within the country.

5.3 The National Number shall contain a three digit area code.

5.4 This number shall correspond to the area code used in the North American Numbering Plan for Telephone Networks.

5.5 Additional addressing information may be provided in an address extension facility containing the amateur callsign and SSID.

5.6 If full 10-digit addressing is desired, the number corresponding to the local exchange and subscriber line may be used.

5.7 If no number is available or if additional numbers are required they should be assigned using exchange numbers in the range of 000 through 199.

5.8 The assignment authority for these exchange and subscriber numbers is limited to the Network Coordinating Agent for that area.

5.9 Service Codes 011, 111, 211, 311, 411, 511, 611, 711, 811, 911 are reserved pending definition by the local Network Coordinating Agent.

5.10 The exchange code 000 is reserved for internal network administration and assignment authority is limited to the National Network Coordinating Agent.

5.11 The exchange code 555 is reserved for internal network administration and assignment authority is limited to the local Network Coordinating Agent.

5.12 The exchange and subscriber code 555-1212 is reserved for regional directory service. Assignment authority is limited to the local Network Coordinating Agent.

6.0 International Number

6.1 The International Number shall consist of the DNIC and the National Number.

6.2 Each National Amateur Network will be capable of interpreting the first four digits of the International Number. This is needed to facilitate routing between networks.

6.3 The use of the DNIC by stations in transit countries would serve as a ready reference for checking third-party traffic-handling requirements.

6.4 The International Number may optionally include a prefix code.

7.0 Formats

7.1 Amateur Network Number Format

P-DDDD-AAA-EEE-NNNN = 15

DDDD-AAA-EEE-NNNN = 14

7.2 Amateur Network Number Format (alternate)

P-DDDD-AAA = 8

DDDD-AAA = 7

Where:

P = Prefix digit
D = Data Network Identication Code
A = Area Code
E = Exchange
N = Number