The Growing Family of Federal Standards for HF Radio Automatic Link Establishment (ALE)

Part III: Where are the Federal Standards for HF ALE Radio Networking Going?

With protocols for basic radio linking established, protocols for networking and higher-level functions are next in line.

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Introduction

Several recent articles have presented an overview of Federal and Military High Frequency (HF) Automatic Link Establishment (ALE) radios to the amateur community.[1,2,3] Other articles describe the standards that must be in place so that government agencies can purchase radios from different vendors and still be assured that they all interoperate.[3] Another recent article describes what may well be the first attempt for amateurs to use HF ALE equipment on amateur frequencies.[4] And a recent series of articles in *QEX* presented you with a view of the "current state and possible future of digital communications in the highfrequency (HP) radio band (3-30 MHz)."[5,6,7,8] To round out the discussion on the present state-of-the-art in HF radio networking, this article presents the Federal HF ALE program prospective. Comparisons will be made between the federal and amateur programs whenever possible.

Amateur Packet Radio

Efforts in the amateur packet-radio community are probably best described in terms of the International Standards Organization (ISO) Open Systems Interconnect (OSI) model.

In general, we look at the communication task and relate it to the OSI model. A representation can be made between the functions of the radio controller and the OSI Reference Model. For the functions associated with the data link layer, almost all amateur packet-radio work is being done with what is commonly known as the AX.25 Data Link Layer Protocol. This protocol has been described in numerous amateur publications over the last few years.

Also described in great detail in numerous amateur publications are the efforts of amateurs to standardize the OSI network and transport layers. An article in a *QST* feature column "Packet Perspective" recently brought us up to date on what is happening in packet networking within the amateur community.[9] This article does an excellent job of summarizing many of the ideas presently being considered in amateur packet radio. The article describes the five most common ideas/attempts at an HF ALE radio solution. Each of these schemes has a set of followers, each attempting to develop the ideal networking solution.

Federal Packet Radio

For many years, the federal community has also been exploring the application of networking technology using packet radio networks. Since 1983, US Government communications groups have been using a packet radio controller to provide data transmission to multiple users on a single radio channel on HF, VHF, and UHF frequencies. This network uses a terminal node controller (TNC), any two-way radio, and the AX.25 protocol.[10]

Not unlike those of the amateur committee, the federal network system requirements are:

1. uncomplicated operator interface and ease of use,
2. rapid access to the network, even

[1]Notes appear on page 19.

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during jamming or poor propagation,
3. continuous operation for all network configurations and propagation conditions,
4. automated routing so that the message gets through even during conditions of very poor connectivity,
5. minimum networking overhead so maximum throughput is obtained,
6. message transmission at all common data rates,
7. connectivity to a wide range of media.

To answer at least the first three of the above requirements, FED-STD-1045 HF ALE radios were developed.[11] FED-STD-1045 radios use a very robust and redundant waveform and have traded data throughput for error control. Items 4 and 5 (ie, advanced networking) are being developed in the continuation standards, proposed FED-STD-1046 and proposed FED-STD-1047. Item 7 is being addressed in proposed FED-STD-1048, which will address multiple-media issues.

Federal HF ALE Radio

To bring you up to speed on the federal effort in HF ALE radio, a recap is necessary. With the recent integration of microprocessor control with state-of-the-art HF radio technology, radios are now being produced that are capable of providing automatic routine and emergency communications while maintaining interoperability between various vendors. Recent federal (see note 11) and military standards are encouraging vendors to produce interoperable (ie, between manufacturers) HF ALE radio systems.[12,13] These radios have features such as selective calling, automatic handshaking, frequency scanning, link quality analysis, and common address group and net calls.

ALE Controller Function Description

A typical ALE radio consists of a HF single-sideband (SSB) transceiver that is connected to a controller to function as an automated HF station. The controller can contain microprocessors or can be an addition to a conventional microcomputer. The present FED-STD-1045 type controller is considered to be a data link-layer controller in terms of the OSI model. The data link controller is roughly equivalent to the amateur TNC. Presently under development are network-layer and transport-layer controllers which will add features of advanced networking to the basic FED-STD-1045 radio. These networking controllers will be standardized by proposed FED-STD-1046 and proposed FED-STD-1047.

ALE radios scan over several channels (frequencies), at two to ten channels per second, looking for traffic. Upon detecting traffic, an ALE radio stops scanning to interrogate for traffic addressed to it; if none is found, it continues scanning. For transmitting, the system has previously determined by Link Quality Analysis (LQA) techniques which channel(s) will do the best job of propagating the message to the distant station. This system assumes that the other members of the network with which you wish to communicate can choose among several frequencies, and the choice may be based on the atmospheric conditions. Through a system of monitoring traffic, sounding, and LQA reporting it has been predetermined which channel(s) in the group will best support a transmission. The transmission is in the form of a link request and contains the address of the originator and the receptor, and can also contain an orderwire message. The actual message can be contained within the orderwire, or it can be indicated to the receptor that a link is requested for voice or modem traffic. After the link-layer controller establishes a link with another station, communication begins. If the message is transferred as part of the link request (as an order-wire mes-

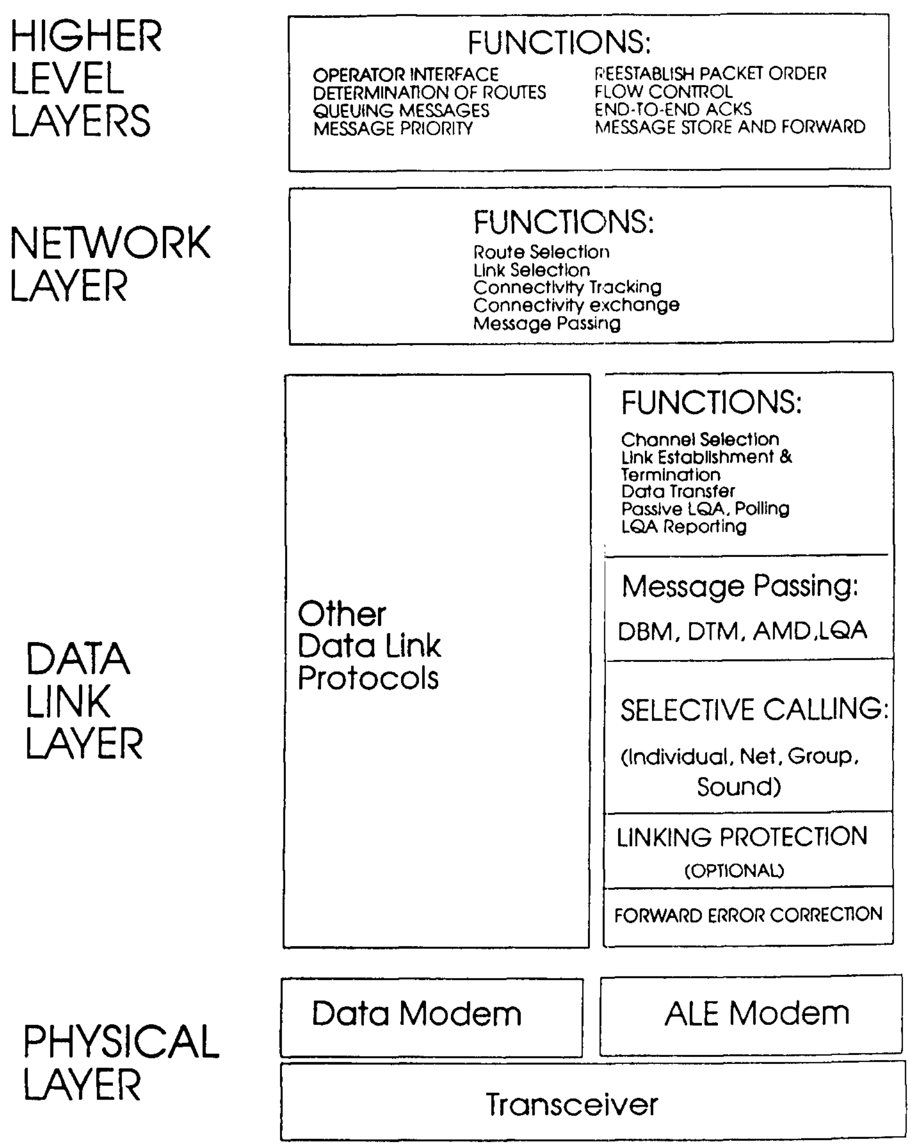

Fig 1—Functional heirarchy of an automated HF station.

sage) or as a data message, it uses a small interval of air-time compared with the time required to send the same message by voice. Therefore, as more and more concepts for networking are developed, the system network throughput will increase.

The principal functions of the station, and the association with the reference model, are schematically shown in Fig 1. When we start adding features such as indirect route selection, connectivity tracking, connectivity (data) exchange (CONEX), automatic message exchange (AME), and automatic message exchange with store-and-forward message exchange (AME w/S&F) we extend into the network and higher-level functions.

Physical Layer Functions

The major function of the controller that relates to the physical layer is that of transceiver and modem (data modem or ALE modem). The data modem used is generally of a MIL-STD-188-110A type, but other possibilities exist. The ALE modem employs 8-ary frequency shift keying (FSK) with 8-millisecond tones, where 3-bit symbols are sent at a rate of 125 per second, giving a raw data rate of 375 bits per second (BPS).

Data Link Layer (DLL) Function

Referring to Fig 1, we see that at the data-link layer, parallel paths exist where the system/user has the option of using a data modem or ALE modem.

a) *Data-Link Layer/Data Modem*—The data-link layer for the data modem is basically a pass-through function, where functions of the network layer act directly on the physical layer function.
b) *Data-Link Layer/ALE Modem*—The lowest layer of the DLL ALE Modem is the Forward Error Correction (FEC) function. Other sublayers add linking protection (optional), selective calling, an orderwire message section, channel selection, link establishment and termination, LQA collection and reporting, and polling functions.

- *Forward Error Correction (FEC)*—This sublayer adds forward error correction, using a Golay code, applied to the ALE words, and each word is sent three times to allow redundancy and majority voting.
- *Linking Protection (optional)*—Linking protection (LP) is a technique that protects the linking functions from unintentional or malicious interference by scrambling the ALE signaling exchanged among protected stations.[14]
- *Selective Calling*—Calls can be made using individual, net, or group station addressing or sounding. The fundamental address element in the ALE system is the individual station address. A net is a prearranged collection of stations called with a net call. A group is non-prearranged collection of stations where little or nothing is known about them except their individual addresses and scanned channels. Sounding is the ability to empirically test selected channels (and propagation paths) by providing a very brief, beacon-like, identifying broadcast which may be used by other stations to evaluate connectivity, propagation, and availability; and to select known working channels for possible later use for communications or calling.
- *Message Passing*—The link-layer message passing by an HF ALE radio, between communicators, might be in an automatic message display (AMD) message, data text message (DTM), data block message (DBM), or LQA mode. The AMD message appears on an 80-character front-panel display device, the DTM is a standard-speed message mode, and the DBM mode message is high-speed (relative to AMD and DTM) with deep interleaving to penetrate HF channel long fades and large noise bursts. LQA concerns the automatic measurement of the quality of the ALE signal on link(s) between stations. The resultant LQA data is used to score the channels and to support selection of a "best" (or an acceptable) channel for calling and communication.
- *Channel Selection*—The primary function of the link-layer HF ALE controller is to monitor receiver channels, choose the best transmit channel, and link with the called station to carry out some function. Linking functions include linking for voice traffic, linking for the transmission of orderwire, and linking to allow transmission of data by an external modem.
- *Link Establishment and Termination*—The data-link function initiates a required response and acknowledgement to complete a three way handshake.
- *Data Transfer*—The data transfer function transfers data such as passive LQA data. Passive LQA data is data obtained from monitoring normal ALE traffic as well as soundings.
- *Passive LQA*—Evaluation of channel quality by measuring the characteristics of received signals is termed passive LQA because the local radio does not transmit a request for this data. Passive LQA data is obtained by listening to normal ALE traffic and soundings (see note 14).
- *Polling*—The polling data link functions are used to acquire current link quality data by using handshaking and exchanges with one or more stations.
- *LQA Reporting*—LQA reporting is the broadcast of data for purposes of updating the memory in other stations in the network.

Amateur Use of Data Link Layer ALE radios

A recent article in *QST*'s "Packet Perspective" column written by Stan Horzepa, WA1LOU, describes what may well be the first amateur band experiment using FED-STD-1045 ALE equipment. "The experiments, which began in June, 1992, were conducted to see how well ALE performs in the noise and interference typical on the amateur bands." (See note 4.) The article gives a brief synopsis of ALE as it exists today, as well as the results of these amateur band tests.

Federal HF ALE Networking

The federal program for advancing HF ALE radio into networking is presently in the definition stage. Protocols are being written that will extend the basic capabilities of the ALE controller into functions associated with the network and transport layers of the OSI model. As an example of the extension of networking to the functions of the ALE controller, we can look at the protocol necessary for providing star group networking functions for prearranged networks that have direct connectivity. The scanning call signal structure of a star group (one station to many) is illustrated in Fig 2 (see note 12).

The Federal HF ALE networking program is presently defining a series of controllers that extends from a very simple networking controller capable of only slave routing to a full-featured HF controller with the ability to hold messages until connectivity (direct or indirect) to the destination is achieved. In general, these controllers can be diagramed as shown in Fig 3.[15]

The FED-STD-1045 HF ALE radio system is not normally thought of as a packet-radio system. Packets are generally associated with internal packet-

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network operation and are not necessarily visible to host computers attached to the network. As the functions of the basic ALE controller are extended to higher and higher levels of the OSI model, these functions begin to take on packet-radio qualities. Message passing between layers will be accomplished as shown in Fig 4 where an example shows a message being passed down through various layers with headers added to eventually be broadcast as a packet in a DTM message. The reverse procedure is used with a received message as each layer strips off the header overhead associated with that layer.

The station originating the message is interested in the transmission of the message from the source station to the destination station. Transmission of the message may be a direct single-path transfer, an indirect multisegment transfer occurring in near real-time, or an indirect multisegment transfer requiring an intermediate station to store the message temporarily until a future path is available. Networking concepts are concerned with end-to-end protocols, networking interface, segmenting and reassembly, sequence numbers, creation and deletion of headers, store and forward functions, routing, local control and lock-ups, network-wide functions and flow control, topology, and network performance.[16]

Networking Layer Control Functions

The functions performed at the network layer may be grouped into two broad categories: routing functions and data management functions. Routing functions select paths through the network for voice and data traffic using link- and path-quality data. Data management functions acquire and communicate that information to a higher level (see note 14). The data that must be maintained is in the form of routing tables and connectivity matrices.

a) Route Selection Function

Routing is an essential element for correct operation of these communication systems. Adaptive routing in particular is required to optimize the use of system resources. When a station cannot be directly linked with a desired destination, other stations may be employed to assist in getting the message through. The simplest option, termed indirect calling, establishes a link with a station other than the desired destination for message passing purposes (see note 14). This indirect calling is the process of sending a message to a station that may have connectivity with the desired station for the purpose of forwarding the message. This may be accomplished either manually (indirect calling) or automatically (relaying),

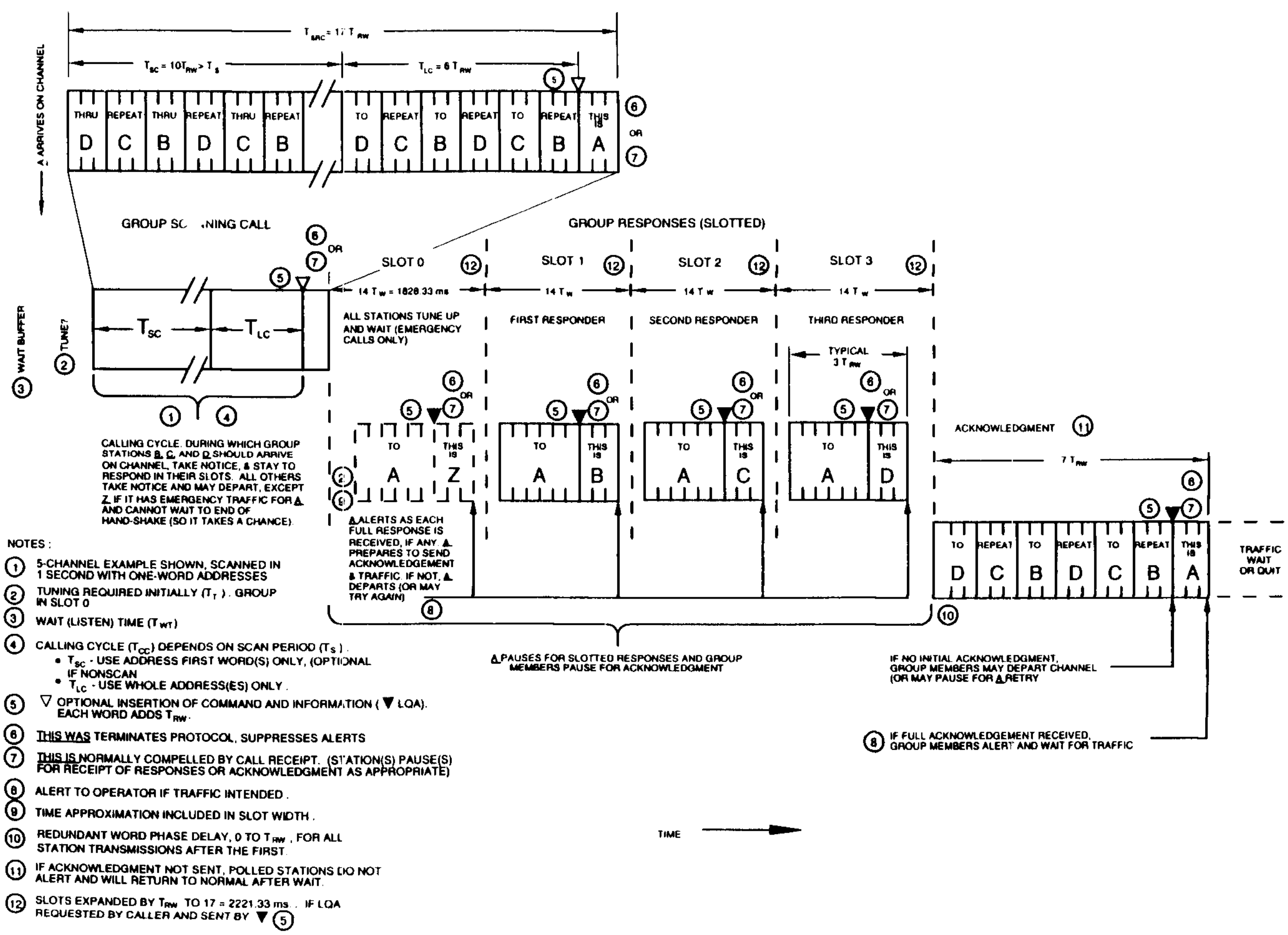

Fig 2—Structure of a star group scanning calling signal.

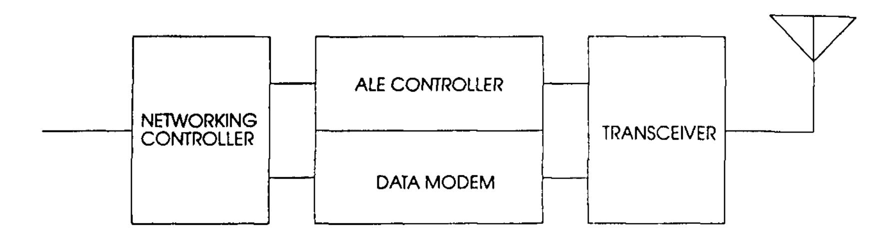

Fig 3—Functional block diagram of an automated station.

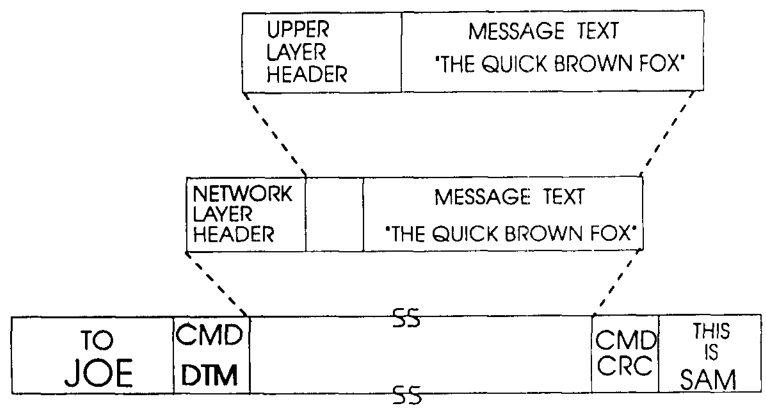

Fig 4—Mapping of upper layers to data link layer DTM.

and may include store-and-forward buffering at intermediate stations.

b) Link Selection Function

The network layer routes the message through the data link controller in the desired manner. One choice may be through a data modem if the message is data and if a data modem is connected. Another choice may be to use the ALE controller and ALE modem. Also, if using the ALE modem, the link selection function must choose to use a sounding, AMD, DTM, or DBM message mode.

c) Connectivity Tracking Function

This function establishes a path quality table to keep track of connectivity. The data stored in a path quality table within the network layer function is obtained from known connectivity, periodic broadcasts, or by request of connectivity exchange (CONEX) data. The data stored in the path quality table is shared with the transport layer function. This layer has responsibility for path determination.

d) Connectivity Exchange (CONEX)

CONEX data can be distributed to other stations on a periodic transmission basis or can be requested/distributed on a demand basis.

e) Message Passing Function

The network layer function must choose to use an orderwire AMD, DTM, or DBM message mode. This may be as an operator real-time message or an Automatic Message Exchange (AME). Since the network function layer does not buffer messages, store-and-forward messages must originate in the higher function layers.

The AME network layer function is defined as the automatic exchange of messages between stations that have direct connectivity with each other. It is the automatic transfer of ALE orderwire data and messages directly from ALE station A to ALE station(s) B (and others), and destined for B (and others), over one of their links with no routing needed.[17]

Transport and Higher-Level Layer Functions

It is the functions of the transport layer and layers above to:

- handshake with the operator
- pass messages down to the network layer
- use the information in the routing and connectivity matrices to determine the direct or indirect route
- instruct the lower layers of the preferred message type (ie, AMD, DTM, or DBM)
- queue messages in case no immediate path(s) is available
- establish message priorities
- re-establish out-of-order packets
- maintain flow control
- keep track of end-to-end acknowledgements, and
- perform the duties of AME (w/S&F) (see below).

Also, there are many other upper-layer functions presently anticipated to be added at a later date.

Automatic Message Exchange with Store-and-Forward (AME w/S&F) is the capability that enables a station to specify a message's routing via indirect relay through another (store-and-forward) station to a destination station.[18] It is the automatic transfer of ALE orderwire data and messages indirectly from ALE station A to ALE station(s) B (and others), through relay(s) C (and others) employing routes and routing as available and based on routing protocols (see note 17). This automatic indirect routing is a transport layer function with decisions based on the use of connectivity exchange information supplied from the network layer function. AME (w/S&F) also includes the capability for a station to automatically accept and store another station's message for direct (or indirect) relay (see note 18).

It is also the function of the higher layers to characterize the system configuration, mission, and topology to meet changing network needs. System configurations affect the routing and networking.

The physical topology is one of the characteristics of the network affected by the network mission. The topology may be a star where the key station might be a national command center. Another choice of topology would be to have a distributed topology where each station has intelligence equal to any other. The location of network stations may change literally minute to minute, as in the case of a system that contains mobile units. It is also possible that the system would only contain fixed-location systems. The network definition tables, output power, and perhaps antenna orientation might be affected by the fixed/mobile nature of the network.

Conclusion

The federal and military communities

have been developing HF ALE radios for many years. There are many fielded radio systems across various government agencies, and the technology is maturing. It is in the area of automatic networking that development work is still being pursued. The architects of these systems are attempting to solve many of the same problems that developers of the Amateur Radio networking effort are experiencing. The functions and features of these ALE radios as well as the interoperability between them has been tested.

Work is ongoing to characterize the performance of HF ALE on actual networks. This work is progressing in network layer simulation studies to determine the effects on message throughput when adding the features of sounding, polling, and networking features.[19]

The federal program for advancing HF ALE radio can be thought of as consisting of a series of hierarchical building blocks for interoperability and operation (see notes 1, 2 and 3). The basic FED-STD-1045 radios are used as building blocks with advanced features such as polling, linking protection, connectivity exchange, automatic message exchange, message store and forward, network coordination, and networking to multiple media added as needed.

Many parallels can be drawn between the effort of federal HF ALE developers and developers of the amateur packet program. These two development efforts are presently struggling with network and transport layer functions while trying to maintain interoperability among the users. The development of these programs using the concepts of OSI has gone a long way in encouraging interoperability. While many of the system constraints are slightly different for the two efforts, in general, they have a lot in common. By diagnosing the efforts of each of these developments, benefits will be received by both.

Many proponents are suggesting a form of ALE for the Amateur Radio community. Work is presently going on to define the networking requirements.

Acknowledgments

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Notes

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