

A Total AUTODIN System Architecture

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Abstract—This paper concerns data communications in the U.S. Department of Defense. It includes a historical perspective on DoD common-user data systems: AUTODIN I, ARPANET, and AUTODIN II. It treats data communications on an end-to-end basis, including automation of communications center functions by the user. The Integrated AUTODIN System Architecture (IASA) project was defined by DoD to provide a total data communications system design on an end-to-end basis. The main results of this paper are based on IASA work and include the use of AUTODIN II as the IAS backbone, the integration of AUTODIN I and AUTODIN II, the definition of a new DoD program called the Inter-Service/Agency Automated Message Processing Exchange (I-S/A AMPE), the development of DoD standard protocols, formats and procedures, a brief description of the IAS security architecture, and a plan for interconnecting different networks via gateways and internet protocols. A plan for the future disposition of the ARPANET is included. The paper concludes with some speculative material on the long-range future of United States military data communications.

I. INTRODUCTION

THIS paper concerns data communications in the Department of Defense. It begins with a brief historical perspective in order to provide context. Then, some of the deficiencies of data communications in the DoD today are outlined. Finally, some plans for growth which will correct these perceived deficiencies and some predictions about the future of data communications in the DoD are provided. Emphasis in this paper is placed on common-user systems. Special DoD data communications networks, for intelligence and command and control applications for instance, are discussed in some of the other papers in this issue.

II. THE BEGINNINGS OF AUTODIN

In the early 1960's, in response to logistics data communications requirements, and to deficiencies identified in DoD message communications during the Cuban missile crisis of 1962, a new program was undertaken by the Defense Communications Agency (DCA), called AUTODIN (Automatic Digital Network) [1]. AUTODIN is an automated, high-speed, computer-based, store-and-forward, worldwide message communications system. AUTODIN uses computers as hosts for magnetic disks that store and forward message traffic in an automated fashion. Such functions as message accountability, multiple addressing, and storage and retrieval of message history files are automated by this system. AUTODIN carries classified traffic, provides community of interest traffic segregation, and provides a precedence system for expedited handling of high-priority traffic. The AUTODIN system currently carries about

a quarter trillion bits per month, and is still the workhorse of DoD data communications. It has been modernized in many ways and currently provides at least limited capabilities to handle computer query/response traffic and facsimile traffic. Most of the traffic carried by AUTODIN today is "data pattern" traffic, comprised of IBM card images or magnetic tape data meant for computer input, rather than "messages" meant to be read by humans.

III. THE ARPANET

In the late 1960's, the Defense Advanced Research Projects Agency (DARPA) initiated a program of research and development of a computer communications system based on the packet-switching principle espoused by Paul Baran in some RAND Corporation reports [2]–[4]. In contrast to AUTODIN, which was not originally intended for real-time application, the packet-switching principle allows less-than-one-second response, so that interactive use of computers is supported. However, all modes of traffic, including bulk data transfer and an informal message service are also supported. Thus, the network which is now known as ARPANET was brought into existence. The ARPANET has grown to become an international network with over 60 switching nodes and 150 host computers. It currently carries about 150 billion bits per month and is managed for the DoD by the Defense Communications Agency as a quasi-operational system, although it still is used for research and development purposes by DARPA, DCA, Military Department laboratories, and others.

IV. THE AUTOMATED MESSAGE PROCESSING EXCHANGE (AMPE)

In the late 1960's and early 1970's, the users of AUTODIN perceived that, while message traffic was carried from communications center to communications center at electronic speed, actual writer-to-reader service was still very slow because of delays between the writer and the communications center, and the communications center and the reader. Each service, and even some defense agencies, began programs of communications center automation to deal with this problem. Since DCA was not authorized to provide automation of communications "behind the AUTODIN mainframe," each service and agency had to provide for its own needs in regard to communications center automation. As a result, a number of projects were initiated: the Navy's Local Digital Message Exchange (LDMX) and Naval Communications Processing and Routing System (NAVCOMPARS); the Army's Automated Multi-Media Exchange (AMME); the Air Force's Automated Telecommunications Program (ATP); and the National Security Agency's STREAMLINER. A generic name has been coined to cover all of these projects, the Automated Message Proc-

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essing Exchange (AMPE). While all the members of the AMPE class have similar attributes, they all differ in detail; in a word, there is little standardization today among the AMPE's.

V. AUTODIN II

In the early 1970's, DCA, in the formulation of long-range plans, articulated a requirement for a packet-switched system which would combine many of the properties of the ARPANET (e.g., fast response for interactive and query/response traffic, and graceful mix of these traffic modes with both computer data transfer and military message traffic) with the military properties of AUTODIN (e.g., capability to handle classified traffic, ability to ensure community-of-interest traffic segregation, ability to preempt network resources for the communication of urgent traffic in times of crisis). In response to this requirement, the Office of Secretary of Defense authorized a new project called AUTODIN II [1]. (To avoid confusion, the original AUTODIN is now referred to as AUTODIN I). In 1976, the AUTODIN II program was formally approved and a contract was signed with Western Union to provide an AUTODIN II service in the continental United States as a tariff offering.

VI. THE INTEGRATED AUTODIN SYSTEM ARCHITECTURE (IASA)

In July of 1974, the General Accounting Office published a report indicating that the Department of Defense should improve the management of AUTODIN terminal procurements by adopting standards which would avoid the costly proliferation of differing solutions to substantially identical requirements. In February of 1975, the Office of the Secretary of Defense tasked DCA to undertake and develop a system concept and design for an "Integrated AUTODIN System Architecture (IASA)." The IASA was to be an end-to-end system architecture which would provide for the orderly growth of DoD data communications on a total system basis. It would provide for standardization of protocols, formats, and procedures; it would provide for the integration of AUTODIN I and AUTODIN II into a single common-user system; it would provide functional specifications for a common family of AUTODIN terminals (including both consolidated automated communications centers—AMPE's—and individual user terminals); it would provide for common-user computer communications, including interfaces to special-purpose systems; and it would determine the manner in which the functions of older systems such as AUTODIN I and ARPANET would be carried on despite the obsolescence of specific hardware [5].

VII. A NEW ROLE FOR AUTODIN II—THE IAS BACKBONE

The AUTODIN II network has been identified as the common-user backbone communications system which will serve as the basic interconnection mechanism for all of the other elements of the Integrated AUTODIN System (IAS). The following attributes are fundamental to AUTODIN II in this role: 1) it is a computer communication system, and the other elements of the IAS are, in fact, computers or computer terminals; 2) it has the security features required of a military sys-

tem; 3) it is an ultrareliable data transport mechanism; 4) it is planned to grow to worldwide dimensions, such that connections to multiple nodes will be generally available everywhere, as a survivability feature; and 5) it provides for a variety of connection methods, including gateways to other networks for interoperability.

VIII. THE MANY KINDS OF AUTODIN II HOSTS

Fig. 1 is a diagram showing the elements of the Integrated AUTODIN System and how they are interconnected. The basic backbone is AUTODIN II, which includes a mesh of packet-switched nodes called switch control modules (SCM's) which are functionally analogous to ARPANET IMP's (Interface Message Processors). Hosts are connected to the SCM's via a Segment Interface Protocol (SIP), and must have the standard Transmission Control Protocol (TCP) to pass useful traffic to other hosts. There are several kinds of hosts.

1) A Terminal Access Controller (TAC) is a special host provided by the network itself to serve those users who wish to connect terminals directly to the network. (User terminals are shown as encircled T's in Fig. 1.) The TAC is the analog of the terminal access portion of an ARPANET TIP (Terminal Interface Processor). It provides standard SIP/TCP protocols, plus the AUTODIN II standard terminal-to-host protocol (THP). TAC's are generally colocated with SCM's to form a total AUTODIN II node, but there are plans for providing remote TAC's (labeled R-TAC in Fig. 1) within AUTODIN II.

2) Another special host of the IAS is the AUTODIN Switching Center (ASC). This is the present-day AUTODIN I switch, which continues to serve as a host to a disc storage system which stores and forwards the formal DoD message traffic. A special protocol will be used among ASC's so that they can exchange message traffic among themselves, as a community of interest, just as they do today over dedicated lines to perform the AUTODIN I functions.

3) Another special type of host of the IAS is the Message Processing Computer (MPC), including the AMPE. Today's AMPE's are connected to AUTODIN I ASC's directly, but our model for the future IAS has them connected to the AUTODIN II backbone, just like any other computer host. They will continue to reach ASC's via the AUTODIN II backbone initially, but later, the ASC hardware will be phased out, although the ASC functions will be assumed by other elements. At that time, AMPE's will obtain message services via a special protocol, to be described in Section XI below. Other MPC's include the NATO TARE (Teletype Automatic Relay Equipment) and the AN/TYC-39 tactical message switch (see Fig. 1). Initially, these systems will continue to be connected to ASC's, but as the ASC hardware is phased out and AUTODIN II switches become ubiquitous, they too can become AUTODIN II hosts sharing in a special MPC protocol. Alternatively, TARE networks and tactical message networks can be connected via the gateway mechanisms described in Section IX below.

4) Users who wish to take advantage of the availability of a reliable, secure, survivable packet-switched backbone can join the network *en masse* as an AUTODIN II subnetwork. Thus,

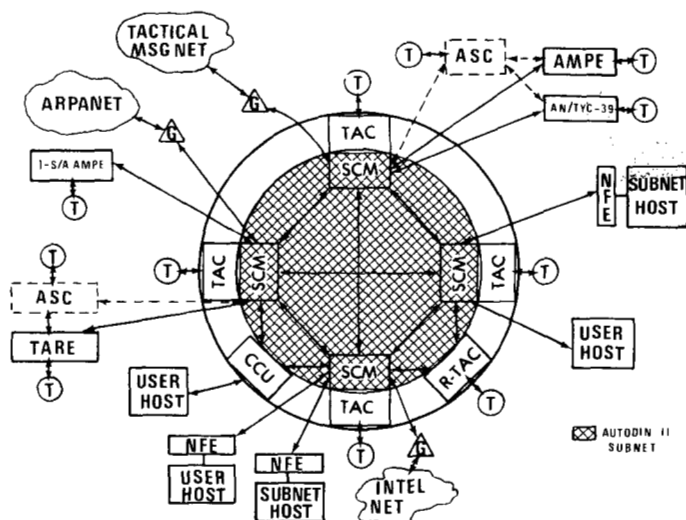


Fig. 1. The Integrated AUTODIN System.

the WIN (WWMCCS Intercomputer Network) and the SACDIN (Strategic Air Command Digital Network) are examples of AUTODIN II subnetworks, and their computers will join the network as hosts sharing in their own special communities of interest (see subnet host in Fig. 1). They will use the AUTODIN II standard SIP and will also be required to use the DoD standard TCP unless they can obtain a waiver from this requirement based on the lack of need to communicate with others beyond their own subnet community of interest.

5) Other computers requiring communications to remote terminals or hosts for any authorized purpose whatever will, of course, be able to join the network as general service subscribers (see user host in Fig. 1). To decrease the burden on host computers to add special networking software, the AUTODIN II design provides a variety of access methods. For example, a Single-Channel Control Unit (SCCU) or Multichannel Control Unit (MCCU) is provided by the contractor and the SIP/TCP/THP software is included in these units, providing for connections of hosts which need to communicate with remote terminals and removing the user's burden of providing that software in his host. Instead, he need only provide relatively simple software to meet a host specific interface in the CCU which would be provided by the AUTODIN II system. Optionally, the user can provide his own SIP/TCP/THP software in his host or in a special front-end processor, so long as this software conforms to the standard specification required of AUTODIN II subscribers.

IX. GATEWAYS AND INTERNETTING

One final AUTODIN II interface remains to be described, and that is an interface not to a host, but to another network via a gateway [6], [7]. (See G's within triangles in Fig. 1.) Although most DoD computer communications users are required to subscribe to AUTODIN II either as general service subscribers or private subnetworks, there remain a few highly specialized networking applications which may justify separate networks. Certain intelligence community applications are in

this category, for example. DoD policy requires, as a minimum, that such special-purpose networks at least be capable of interfacing to AUTODIN II via gateways to provide for interoperability, restoral of connectivity in crisis situations, and the like. Moreover, gateways can provide temporary or permanent connectivity among AUTODIN II subscribers and subscribers of such diverse networks as ARPANET, future tactical packet radio networks, tactical and allied military message communications networks, and a wide variety of local networks. To achieve this desired interoperability, it is required that the subscribers of internettted systems use a common standard TCP and Internet Protocol (IP) [8]-[11]. DoD policy has recently been stated which requires DoD data network subscribers having requirements for interoperability to adhere to these standards. What remains is for the gateways themselves to be developed and implemented. A research and development program to develop the gateways is now underway under the aegis of Rome Air Development Center.

X. THE INTERSERVICE/AGENCY AMPE

Authority for DCA to proceed with an Interservice/Agency (I-S/A) AMPE program has recently been granted. The I-S/A AMPE is one element within the common family of AUTODIN terminals. It will be implemented in phases. The first phase, targeted for implementation in 1985, will provide an AMPE having the capability to perform the automated telecommunication center functions in a standard way. It will feature an access control mechanism which will guarantee separation of user traffic by security category and community of interest, a host-type interface to an AUTODIN II SCM, and a virtual message protocol, described below in Section XI, which will enable the I-S/A AMPE to assume many of the functions of the AUTODIN I ASC's, so those equipments can be phased out of the inventory. The I-S/A AMPE will be modular in both its hardware and software design, such that user-unique software modules will be able to be added to the repertoire of standard modules in a graceful manner. DoD intends to acquire I-S/A AMPE hardware and software competitively using a "software-first" approach. Thus, these systems will be procured to run software written in a standard high-level language which will have appropriate compilers and other software engineering tools available within a broad class of hardware options. Post-1985, later phases of the I-S/A AMPE will be implemented which will provide additional, presently undefined capabilities on a value-added basis to satisfy future requirements. Examples of these future, as yet speculative services, include data teleconferencing, facsimile, electronic mail, and word processing.

XI. A VIRTUAL MESSAGE PROTOCOL

The I-S/A AMPE will include a Virtual Message Protocol (VMP) which will provide for carrying out the functions presently associated with AUTODIN I (multiple addressing, message storage and retrieval, etc.). These same functions are required for informal message service as well, such as those currently available to ARPANET users under the titles of

MSG, HERMES, SIGMA, etc. [12]. Once the VMP is available, both formal and informal message systems will be able to use the basic message transfer mechanism. Different user interfaces will have to be provided to implement the various message services desired, including classical AUTODIN I service as one example. The availability of the I-S/A AMPE will permit the phase-out of AUTODIN I hardware; moreover, any host whatsoever, endowed with the VMP and appropriate user interface software, will be able to act as a surrogate ASC. This concept, together with the internetting concept described in Section IX above, has the potential to provide greater survivability of the vital AUTODIN I service, and also to provide for interoperability among strategic, tactical and allied message service users by providing systems such as the AN/TYC-39 and the NATO TARE with the VMP and relevant user interface software.

XII. SECURITY ARCHITECTURE

Because security is such an important requirement for military systems, one must include appropriate security mechanisms within the architecture from the start. Another paper in this issue [13] deals with this problem in some depth. Suffice it to state here, that current plans for security mechanisms in the architecture of the IAS are as follows: 1) AUTODIN I currently provides for encryption of classified traffic, and traffic segregation mechanisms which prevent mixing of traffic belonging to different "need-to-know" security classes; 2) AUTODIN II, from its initial operation, will also provide for encryption of all classified traffic, and will, in addition, incorporate an improved traffic segregation mechanism based on security kernel technology [11]; 3) the design of the I-S/A AMPE will include an access control mechanism, as mentioned in Section X above; and 4) in the late 1980's it is planned to add an end-to-end encryption capability to the IAS, so that transmitted data will remain encrypted through all intermediate stages of the communications process. It should be noted that the security mechanisms provided within the IAS will be in addition to those provided by users for their host and terminal areas. In particular, security provisions of the IAS will supplement but not substitute for solutions to the host multi-level security problem.

XIII. THE FUTURE OF THE ARPANET

Once AUTODIN II is fully operational, it will be able to provide computer communications services to many of the users who currently subscribe to the ARPANET. In fact, for operational military users, the AUTODIN II service will be preferred because of the military features which it provides. Those ARPANET users who are not authorized use of military communications by DoD policy will find that common carrier and commercial value-added carrier services will be available to meet their requirements. However, those ARPANET users who continue to need a test-bed type network to support research and development on packet switching technology, will not be able to satisfy their requirements by subscribing to either AUTODIN II or a commercial service. Accordingly, a requirement has been identified for continuation of a test-bed

type ARPANET. Thus, the plan for ARPANET is for it to diminish significantly in size, but to continue to exist as an entity to support DoD research and development experiments in packet switching technology and to provide a test bed for development of such applications as distributed database concepts for command and control. Note that the internet/gateway concepts will provide for continuity of communities of interest during the transitional period that some members of a given community are subscribers to different networks. This is, of course, subject to the provision that these subscribers use appropriate standard TCP and IP protocols and that the gateways between the relevant networks are implemented.

XIV. LONG-RANGE PREDICTIONS

It will be the mid- to late 1980's before all of the architectural elements of the IAS described so far will begin to merge into a viable total system. In the meantime, certain other parallel developments will be underway. These include the development of multiple access protocols for efficient use of a packet-mode satellite broadcast capability, and the development of packetized speech and packetized teleconferencing protocols. As we move into the 1990's and approach the end of this century, the merger of digital data traffic and digital speech traffic seems certain to occur. Whether this will happen in a packetized mode, or by more conventional time-division multiplexing and switching, or by some combination of these techniques remains to be seen. Perhaps the most likely method of integrating voice and data communications in the near term is the one discussed by Coviello and Lyons in this issue [14]. This involves use of a broad band circuit-switched network at the apex of the network nodal hierarchy, which would provide for flexible interconnection among SCM's in the shaded portion of Fig. 1. In any case, one thing is certain. The merger of telecommunications and data processing will continue unabated. Computer control of telecommunications functions is already a reality, and it is an irreversible process. New protocols will continue to be developed, for the protocols are the rules and procedures by which processes in computers communicate with one another. Protocol development and standardization are where the action is in data telecommunications systems engineering of the future.

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