ARPAnet/IMP Software History

PRINCIPAL MILESTONES

	nodes	
1969	4	Initial network — 4 IMPs — DDP 516 50 Kb circuits
1970	13	Distant hosts 230.4 KB circuits
1971	19	H316 IMP (lower cost) Directly connected terminals via TIP
1972	34	Magnetic tape handler for TIP Improved algorithms for flow control and storage allocation
1973	45	Satellite links to Hawaii and Europe Interconnection with foreign PTTs Reliability and Routing improvements Very distant hosts (via modems)
1974	51	Shift of emphasis to operational reliability TIP access control and accounting Logical subnetworks Selective memory checking and reloading
1975	58	Host access controls and “fairness” improvements High-reliability, high-throughput multiprocessor IMPs ARPANET operation to Defense Communications Agency Multi-access satellite network Private line interface (PLI) for data security Transmission of digital speech

1976	58	New terminal support protocol
		Expanded host and IMP address ranges
		Consolidation and emphasis on operational stability
1977	58	Distributed terminal control protocol (RCTE)
		Support of digital circuits (DDS)
		Routing study and consequent improvements
		Honeywell Level 6 processor support
		X.25 Link Access Protocol
1978		Major routing study underway
		Increased Host fan out (Level 6)
		Packet size as parameter (Level 6)
		X.25 Level 3

EVOLUTION OF THE ALGORITHMS

1969 Reliable communications subnetwork

Delay of 1/2 second or less

Independence of hosts and IMPs

Hosts transmit messages (up to 8095 bits)

IMPs segment messages into packets (up to 1008 bits) which are transmitted independently and in parallel to reduce delay

Limit of one outstanding message per conversation between one pair of hosts to prevent congestion

Specially designed asynchronous bit-serial host to IMP interface

24 bit hardware checksum

Packets forwarded to next IMP and stored pending positive acknowledgement of receipt (up to 8 outstanding)

Distributed adaptive routing algorithm

- minimum delay based on estimates from neighbors and own knowledge of queuing delay and line condition
- no need to know full topology
- self-adjusting
- efficient

1972 Regular exchange of line, host and IMP status

Changes to improve performance under heavy loads (based on conclusions from experiments and simulations)

Pre-allocation of buffers for multi-packet messages to ensure timely re-assembly at destination

ACKs imbedded in normal messages

1973 “Hold down” logic added to damp response to new line or node data in order to prevent temporary looping

Sensing of line speed and capacity and adjustment of routing information exchange frequency

Event-driven routing calculation

1974 “Raw packets” — sequencing and flow control logic bypassed
Dynamic rather than static accounting for allocation and flow control data
Allocation by Host pair (previously by IMP pair)
Singly connected IMPs
Inter-IMP message number re-synchronization

1975 Expanded number of outstanding messages per host pair
More complete message state information at destination IMP

1976 Expanded formats for host and IMP addresses
Consolidation of information about pending messages into uniform transaction blocks

1977 Provision for up to 16 outstanding packets on lines with long delay (e.g., satellite links)
Improved calculation of re-assembly and store/forward storage limits
Preliminary routing study and changes to contain and more rapidly correct congestion arising from bad lines or slow nodes
Host and modem interfaces made equivalent (Level 6)
Use of BSC for error detection and data transparency (Level 6)
Use of HDLC for error recovery and acknowledgement (Level 6)

1978 Major routing study underway to incorporate most recent research and current experience
Provision for 12 or more hosts per IMP (Level 6)
Packet size made a parameter (Level 6)

EVOLUTION OF MAINTENANCE AND CONTROL FUNCTIONS

1969 Performed by system programmers and hardware designers on a casual basis
Remote controlled diagnostic loopback
Power failure detection and recovery
Watchdog timer and self-initiated reload from neighbor
Packet tracing
State snapshots
Remote debugging package
Performance statistics

1970 Centralized trouble reporting and diagnosis
Exception-based problem reporting
Distribution of new software via the network itself

1971 Introduction of host NCC processor to monitor network status and prepare reports
Dedicated prime-shift NCC operator

1972 Loading of TIPs from NCC host
Broadcast patching of IMPs from NCC host
Full-time NCC operator coverage
Responsibility for operations assigned to operators
Fully remote software distribution
Use of large host for some NCC functions

1973 Software-generated checksums for both data and software; self-initiated dump and re-load
Addition of remote IMP hardware diagnostics
Remote scanning for malfunctioning TIP terminal modems

1974 Selective reloading of IMP/TIP software
On-line notification and status for host down-time

1975 Transfer of ARPANET to DCA administration as an operational utility
Statistics and trace modules made selectively loadable

1976 Improved load and dump routines
Auto-sensing of line and host configuration
Emphasis on stability
Consolidation

1977 Disk-based Network Monitoring Center
Diskette-based Network Monitoring Center
Error control on Host/IMP channel (Level 6)