Table 2. TCP, UDP, TP4, TP0

General Features	TCP (Internet)	UDP (Internet)	TP4 (OSI)	TP0 (OSI)
Well suited for	Stream transport over unreliable networks	Applications where normal case is operation over LAN with low loss rates (e.g., NFS, SNMP)	Message-oriented transport over unreliable networks	Message-oriented transport over reliable networks
Developed for	General purpose reliable data communication over unreliable networks	General purpose datagram transport with minimum of protocol mechanism	General purpose reliable data communication over unreliable networks	Minimum function protocol over reliable CO networks
Features for special applications	Nagle algorithm[1] for interactive data	None		Oriented for teletext; OSI–TCP gateway[2]
Underlying service	IP	IP	Unreliable network	Reliable CO network (e.g., X.25)
Has been implemented in	Software	Software	Software	Software

Service Features	TCP (Internet)	UDP (Internet)	TP4 (OSI)	TP0 (OSI)
CO-byte vs CO-message vs CL	CO-byte	CL	CO-message	CO-message
Reliability				
No-loss vs Uncontrolled-loss vs Controlled-loss	No-loss	Uncontrolled-loss	No-loss	No-loss[3]
No-duplicates vs Maybe-duplicates	No-duplicates	Maybe-duplicates	No-duplicates	No-duplicates[3]
Ordered vs Unordered vs Partially-ordered	Ordered	Unordered	Ordered	Ordered[3]
Data-integrity vs No-data-integrity vs Partial-data-integrity	Data-integrity	Data-integrity and No-data-integrity[4]	Data-integrity	Data-integrity[3]
Multicast vs Unicast	Unicast	Unicast[5]	Unicast	Unicast
Priority vs No-priority	No-priority	Priority	Priority	Priority
Security vs No-security	No-security	No-security	Security[6]	Security[6]

[1] Since interactive data TPDUs often carry 1 byte of user data, overhead of 40-byte header (20 for TCP; 20 for IP) adds to congestion in WANs. Therefore, Nagle Algorithm restricts a TCP connection to having at most one outstanding unacknowledged small TPDU. No additional small TPDUs can be sent until the ACK is received.
[2] TP0 can be used to create OSI transport service on top of TCP's reliable byte-stream service, enabling OSI apps to run over TCP/IP [RFC 1006].
[3] Assumed to be part of the underlying network service.
[4] UDP provides an optional checksum on the header and user data.
[5] UDP can provide multicast service with IP support.
[6] Protection is a QoS parameter that can be specified as protection against passive monitoring, passive modification, replay, addition, or deletion.

Table 2 (cont'd). TCP, UDP, TP4, TP0

Protocol Features	TCP (Internet)	UDP (Internet)	TP4 (OSI)	TP0 (OSI)
CO vs CL Protocol	CO	CL	CO	CO
Transaction-oriented	No	No[1]	No	No
CO Protocol				
In-band vs Out-of-band Signaling	In-band	N/A	In-band	In-band
Unidirectional vs Bidirectional conn	Bidirectional	N/A	Bidirectional	Bidirectional
Conn establishment	3-way	N/A	3-way	3-way
User data in conn Establishment	Not permitted[2]	N/A	Permitted[3]	Not permitted
Conn termination	4-way	N/A	3-way	N/A[4]
Acknowledgments				
Piggybacking	Yes	N/A	Yes	N/A[5]
Cumulative vs Selective	Cumulative[6]	N/A	Selective	N/A[5]
Sender-dependent vs Sender-independent	Sender-dependent	N/A	Sender-dependent and optional Sender-independ	N/A[5]
Error Control				
Error detection	Sequence no; Checksum on header and data	Optional checksum on header and data	Sequence no; Length field; Optional checksum on header and data	No
Error reporting	No	No	No	No
Error recovery	PAR	No	PAR	No
Flow/Congestion Control				
End-to-end flow control	Window	No	Window	Backpressure[4]
Window allocation	Byte-oriented	N/A	TPDU-oriented	N/A
Rate control parameters	N/A	N/A	N/A	N/A
Congestion control	Implicit access control	No	Implicit access control	No
TPDU Format				
TPDU numbering	Byte-oriented	No	TPDU-oriented	No
Min TPDU header/trailer	20-byte header	8-byte header	5-byte header	3-byte header
Multiplexing/Demultiplexing	Yes	Yes	Yes	No
Splitting/Recombining	No	No	Yes	No
Concatenation/Separation	Yes[7]	No	Yes	No
Blocking/Deblocking	Yes[8]	No	Yes	Yes
Segmentation/Reassembly	Yes	No	Yes	Yes

[1] But frequently used for transaction based applications.
[2] While data may be sent in TCP connection opening TPDU, it cannot be delivered to user receiver until 3-way-handshake is complete.
[3] Not > 32 octets. This data (eg, password) may help decide if connection should be established, thereby allowing estab to depend on user data.
[4] Assumed to be part of the underlying network service.
[5] There are no ACKs in TP0.
[6] A version of TCP which combines selective ACKs and cumulative ACKs has been specified [RFC 2018].
[7] Data and ACK TPDU is concatenated in the case of piggybacking.
[8] However, boundaries are not preserved between transport sender and transport receiver.

Table 3. NETBLT, VMTP, T/TCP, RTP

General Features	NETBLT (Internet)	VMTP (Internet)	T/TCP (Internet)	RTP (Internet)
Well suited for	Long-delay paths	Transactions	Transactions	Real-time data
Developed for	Bulk data transfer	Remote Procedure Calls, multicast, real-time communication	Improving TCP performance for transaction processing	Real-time, multi-participant multimedia conferences
Features for special applications	User controlled window-based flow control	Naming mechanism for process migration, mobile hosts; Conditional message delivery for real-time application; Optimized for page-level network file access; Call forwarding	3-way can be bypassed; Shorter delay in TIME-WAIT state	Integrated layer processing; QoS feedback; Can be tailored to specific applications; Mixing, translating via SSRC fields
Underlying service	IP	Datagram network	IP	UDP[1], AALs
Has been implemented in	Software	Software	Software	Software

Service Features	NETBLT (Internet)	VMTP (Internet)	T/TCP (Internet)	RTP (Internet)
CO-byte vs CO-message vs CL	CO-message[2]	CL	CO-byte and CL[3]	CL
Reliability				
No-loss vs Uncontrolled-loss vs Controlled-loss	No-loss	No-loss	No-loss	Uncontrolled-loss
No-duplicates vs Maybe-duplicates	No-duplicates	No-duplicates	No-duplicates	No-duplicates
Ordered vs Unordered vs Partially-ordered	Ordered	Ordered	Ordered	Unordered
Data-integrity vs No-data-integrity vs Partial-data-integrity	Data-integrity	Data-integrity	Data-integrity	No-data-integrity
Multicast vs Unicast	Unicast	Multicast and Unicast	Unicast	Unicast[4]
Priority vs No-priority	No Priority	Priority	No-priority	No Interrupt/Priority
Security vs No-security	No Security	Security[5]	No-security	Security

[1] RTP may be used with other suitable underlying network or transport protocols.
[2] In this case message is a "buffer" as explained in section 5.4.
[3] T/TCP provides CO or CL service. For CO service, transport user has to issue the *open*, *send*, and *close* primitives as in TCP. For CL service, only the *sendto* primitive is required.
[4] RTP can provide multicast service if available in lower layer protocols.
[5] VMTP's security feature was designed but never implemented.

Table 3 (cont'd). NETBLT, VMTP, T/TCP, RTP

Protocol Features	NETBLT (Internet)	VMTP (Internet)	T/TCP (Internet)	RTP (Internet)
CO vs CL protocol	CO	CO	CO	CL[1]
Transaction-oriented	No	Yes	Yes	No
CO protocol				
In-band vs Out-of-band signaling	In-band	In-band	In-band	N/A
Unidirectional vs Bidirectional conn	Unidirectional	Unidirectional	Bidirectional	N/A
Conn establishment	2-way	Implicit	3-way and Implicit	N/A
User data in conn Establishment	Not permitted	Permitted	Permitted	N/A
Conn termination	2-way	Implicit	4-way	N/A
Acknowledgments				
Piggybacking	N/A	No[2]	Yes	N/A
Cumulative vs Selective	Cumulative	Selective	Cumulative	N/A
Sender-dependent vs Sender-independent	Sender-dependent	Sender-dependent	Sender-dependent	N/A
Error Control				
Error detection	Sequence No; Length field; Header checksum; Optional data checksum	Transaction ID; Length field; Checksum on header and data	Sequence No; Checksum on header and data	Sequence No
Error reporting	Selective reject	Selective reject	No	Special reports[3]
Error recovery	ARQ with selective retransmission	ARQ with selective retransmission	PAR	No
Flow/Congestion Control				
End-to-end flow control	Window and Rate	Rate	Window	No
Window scheme	Buffer-oriented	N/A	Byte-oriented	N/A
Rate control parameters	Burst size and rate	Interpacket delay	N/A	N/A
Congestion control	No	Implicit access control	Implicit access control	No[4]
TPDU Format				
TPDU numbering	TPDU-oriented	TPDU-oriented	Byte-oriented	TPDU-oriented
Min TPDU header/trailer	24-byte header	64-byte header	24-byte header	12-byte header
Multiplexing/Demultiplexing	Yes	Yes	Yes	Yes[5]
Splitting/Recombining	No	No	No	No
Concatenation/Separation	No	No	No	No
Blocking/Deblocking	No	No	Yes	No
Segmentation/Reassembly	Yes	Yes	Yes	No

[1] RTP has no notion of a connection; however RTCP provides out-of-band signaling.
[2] Normally a response implicitly acks request; each new request implicitly acks last response rec'd. Thus VMTP provides implicit but not explicit piggybacked ACK info.
[3] Sender and Receiver reports are exchanged via RTCP, a control protocol that monitors data delivery and provides minimal control and id functions.
[4] Application may perform congestion control by using the QoS feedback provided by the RTCP control messages.
[5] Via synchronization source identifier (SSRC) field.

Table 4. SNA/APPN, DECnet/NSP, XTP, ATM/SSCOP/AAL5

General Features	APPN (SNA)	NSP (DECnet)	XTP	SSCOP/AAL5 (ATM)
Well suited for	Distributed systems	Message oriented over unreliable networks; dist'd systems	Reliable transport multicast; Real-time datagrams; Fast connection setup	High speed reliable data and control signaling
Developed for	Diverse platforms, topologies, and apps into single network	General purpose reliable data comm over unreliable nets	Single protocol separates policy from mechanism; VLSI implementation	ATM networks
Features for special applications	Class of Service selection[1]	Expedited data	Out-of-band data[2]; Orthogonality; Selectable flow and error control	block PACKs/NACKs
Underlying service	APPN network layer (virtual circuit)	DECnet layer 3 protocol	Any network layer[3] or directly over LLC, MAC, ATM AALs	ATM
Has been implemented in	Software		Software[4]	Software and Hardware

Service Features	APPN (SNA)	NSP (DECnet)	XTP	SSCOP/AAL5 (ATM)
CO-byte vs CO-message vs CL	CO-message	CO-message	CL and CO-byte	CO-message
Reliability				
No-loss vs Uncontrolled-loss vs Controlled-loss	No-loss[5]	No-loss	No-loss and Uncontrolled-loss	No-loss
No-duplicates vs Maybe-duplicates	No-duplicates[5]	No-duplicates	No-duplicates and Duplicates	No-duplicates
Ordered vs Unordered vs Partially-ordered	Ordered[5]	Ordered	Ordered and Unordered	Ordered
Data-integrity vs No-data-integrity vs Partial-data-integrity	Data-integrity[5]	No-data-integrity	Data-integrity and No-data-integrity	Data-integrity[6]
Multicast vs Unicast	Unicast	Unicast	Multicast and Unicast	Unicast
Priority vs No-priority	Priority	Priority	Priority	Priority[7]
Security vs No-security	Security	No-security	No-security	No-security

[1] COS-based routing is provided by APPN network layer. APPN transport takes advantage by using different service classes.
[2] Useful for passing control info about state of transport user processes, or passing semantic info about data, or for event sequencing via timestamps.
[3] Most of all XTP implementations operate over IP.
[4] XTP was designed for but never implemented in VLSI.
[5] Provided by the underlying network.
[6] Assumed to be provided by underlying service. SSCOP itself has no checksum.
[7] I.365.3 allows optionally expedited data using SSCOP unassured data delivery.

Table 4 (cont'd). SNA/APPN, DECnet/NSP, XTP, ATM/SSCOP/AAL5

Protocol Features	APPN (SNA)	NSP (DECnet)	XTP	SSCOP/AAL5 (ATM)
CO vs CL protocol	CO	CO	CO	CO
Transaction-oriented	Yes	No	Yes	No
CO protocol				
In-band vs Out-of-band signaling	Out-of-band	In-band	In-band	N/A[1]
Unidirectional vs Bidirectional conn	Unidirectional and Bidirectional	Bidirectional	Bidirectional	Bidirectional
Conn establishment	2-way		Implicit	2-way
User data in conn establishment	No	Yes	Permitted	Yes[2]
Conn termination	2-way		4-way[3]	2-way
Acknowledgments				
Piggybacking	N/A[4]	Yes	No	No
Cumulative vs Selective	N/A[4]	Both	Selective	Both[5]
Sender-dependent vs Sender-independent	N/A[4]		Sender-dependent	Sender-dependent[6]
Error control				
Error detection	No[7]	Sequence No	Sequence No; Length field; Header checksum; Optional data checksum	Sequence No; Checksum on header and data
Error reporting	No[7]		Selective reject	Selective reject[8]
Error recovery	No[7]	PAR	ARQ with Go-Back-N (optional sel retrans)	ARQ with selective repeat
Flow/Congestion control				
End-to-end flow control	N/A[9]	Window	Window and Rate	Window-credit
Window scheme	N/A[9]	TPDU(segment)-oriented	Byte-oriented	TPDU-oriented
Rate control parameters	N/A[9]	N/A	Burst size and rate	N/A
Congestion control	N/A[9]	Explicit access control	Explicit access control	No[10]
TPDU format				
TPDU numbering	TPDU-oriented	TPDU-oriented	Byte-oriented	TPDU-oriented
Min TPDU header/trailer	9-byte header		32-byte header	
Multiplexing/Demultiplexing	No	No	Yes	No
Splitting/Recombining	No	No	No	No
Concatenation/Separation	No	Yes[11]	No	No
Blocking/Deblocking	No	No	No	No
Segmentation/Reassembly	Yes	Yes	Yes	Yes

[1] See Section 5.11.
[2] But no guarantee of delivery.
[3] XTP also employs 2-way-handshake and abortive close modes of connection termination.
[4] APPN does not need ACKs because it assumes a fully reliable network service.
[5] STAT is full map of missing/ACKed PDUs.
[6] Sender periodically polls receiver.
[7] Responsibility of the underlying network.
[8] Transport receiver sends one USTAT (NACK) which provides selective reject info for every missing PDU.
[9] APPN does not perform flow/congestion control at transport layer; relies on network layer's "adaptive pacing".
[10] Local flow control backoff is discussed, but not specified/standardized.
[11] Data and ACK TPDU is concatenated in the case of piggybacking.