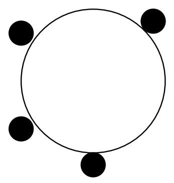
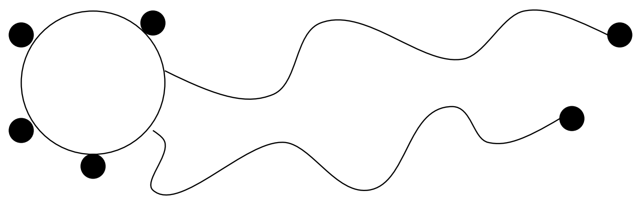
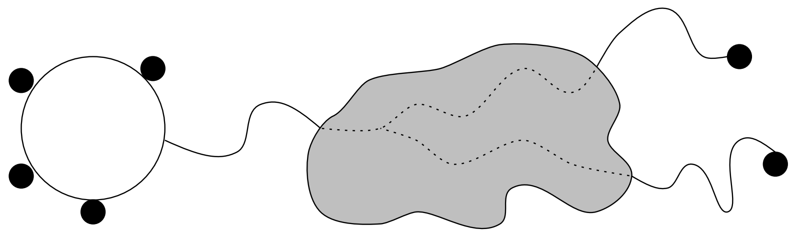


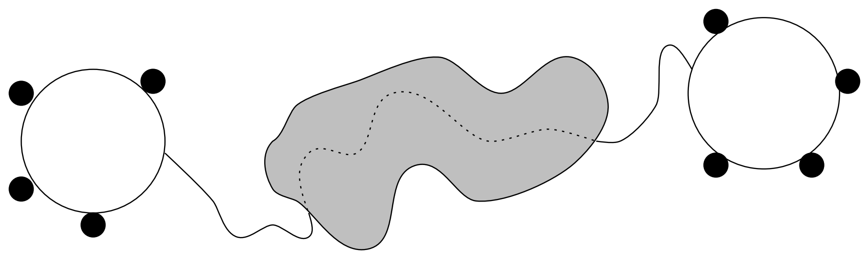
(a) computer with only directly-connected input/output devices



(b) computer with remotely-connected input/output terminals

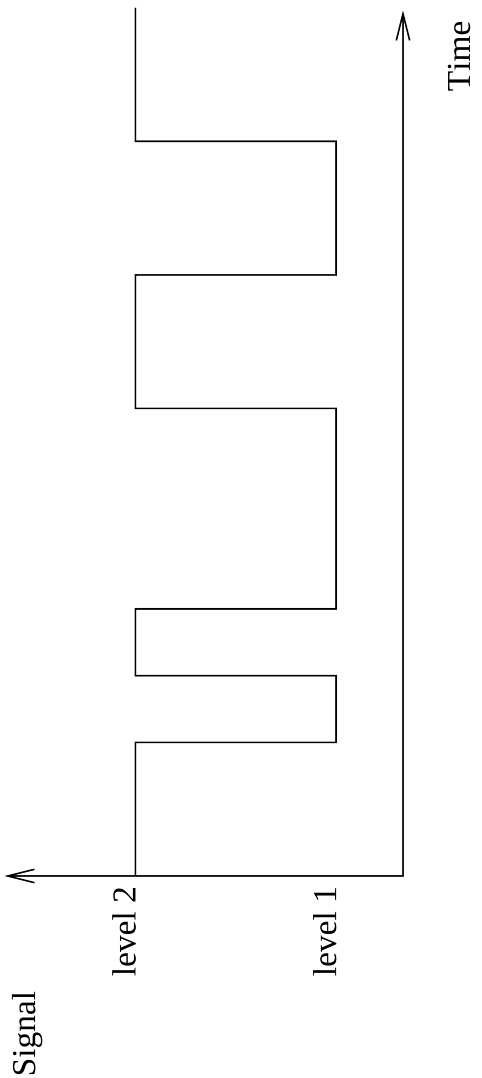


(c) computer with terminals connected via communication service

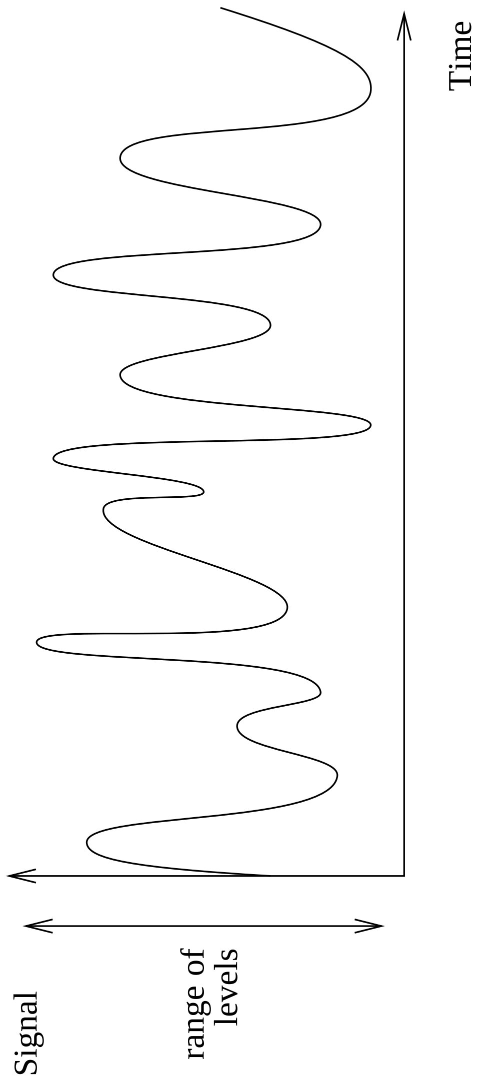


(d) computers connected via communication service

# Evolution of computer-oriented communications

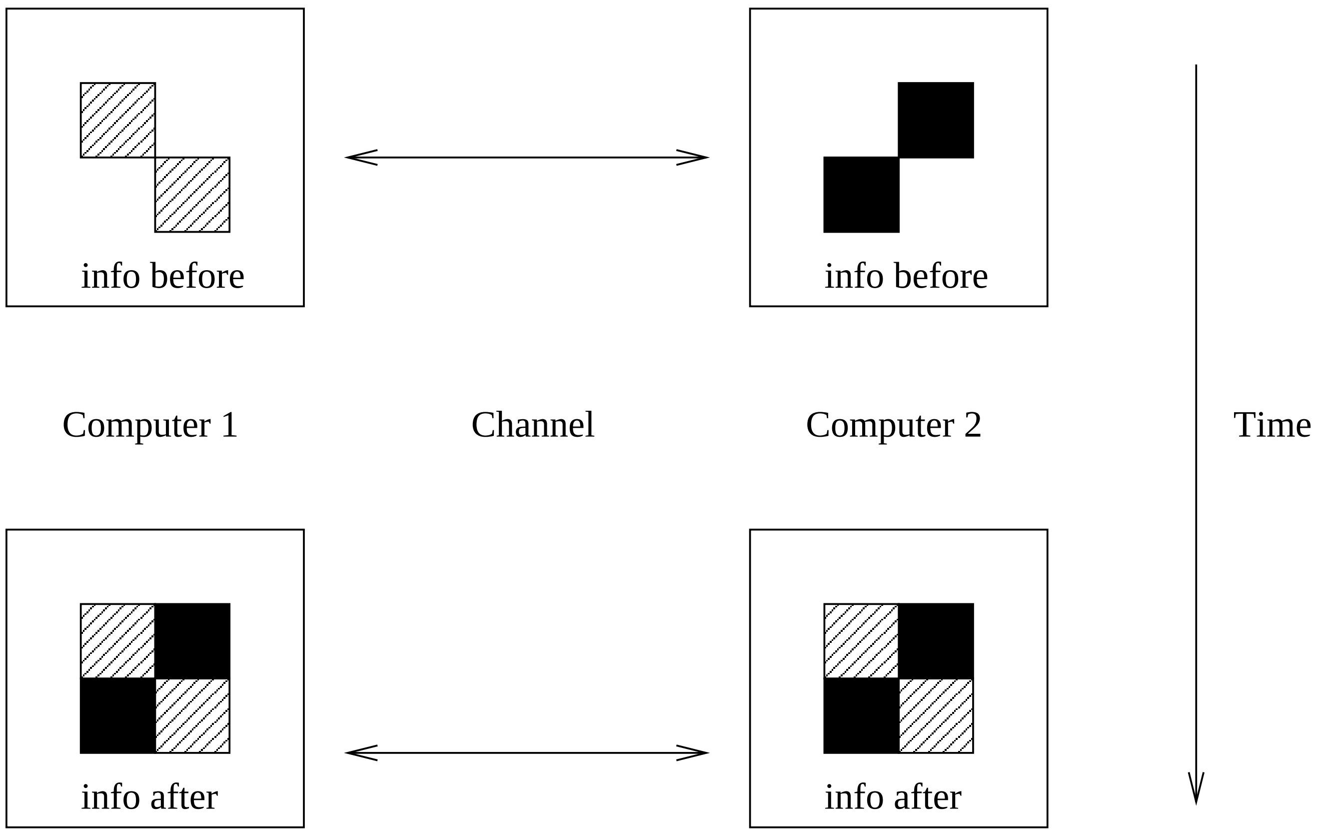



(a) digital signal with two different levels

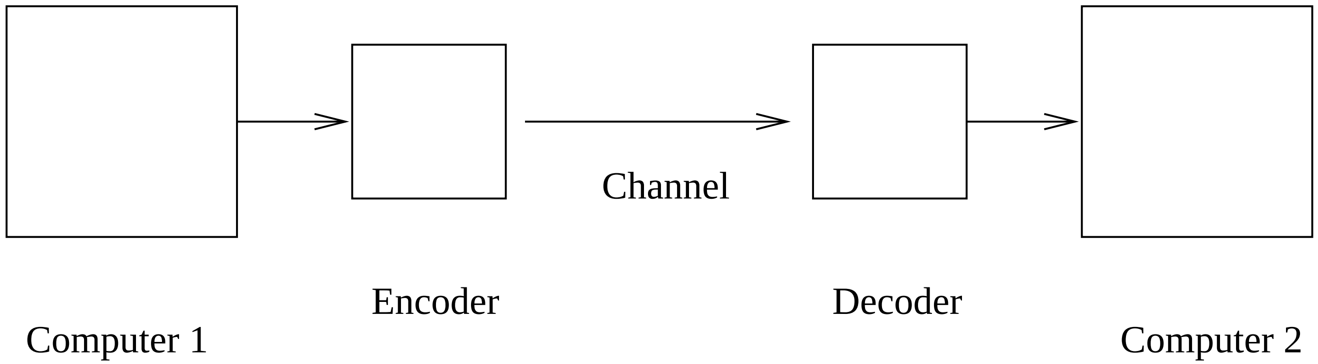



(b) analogue signal over range of levels

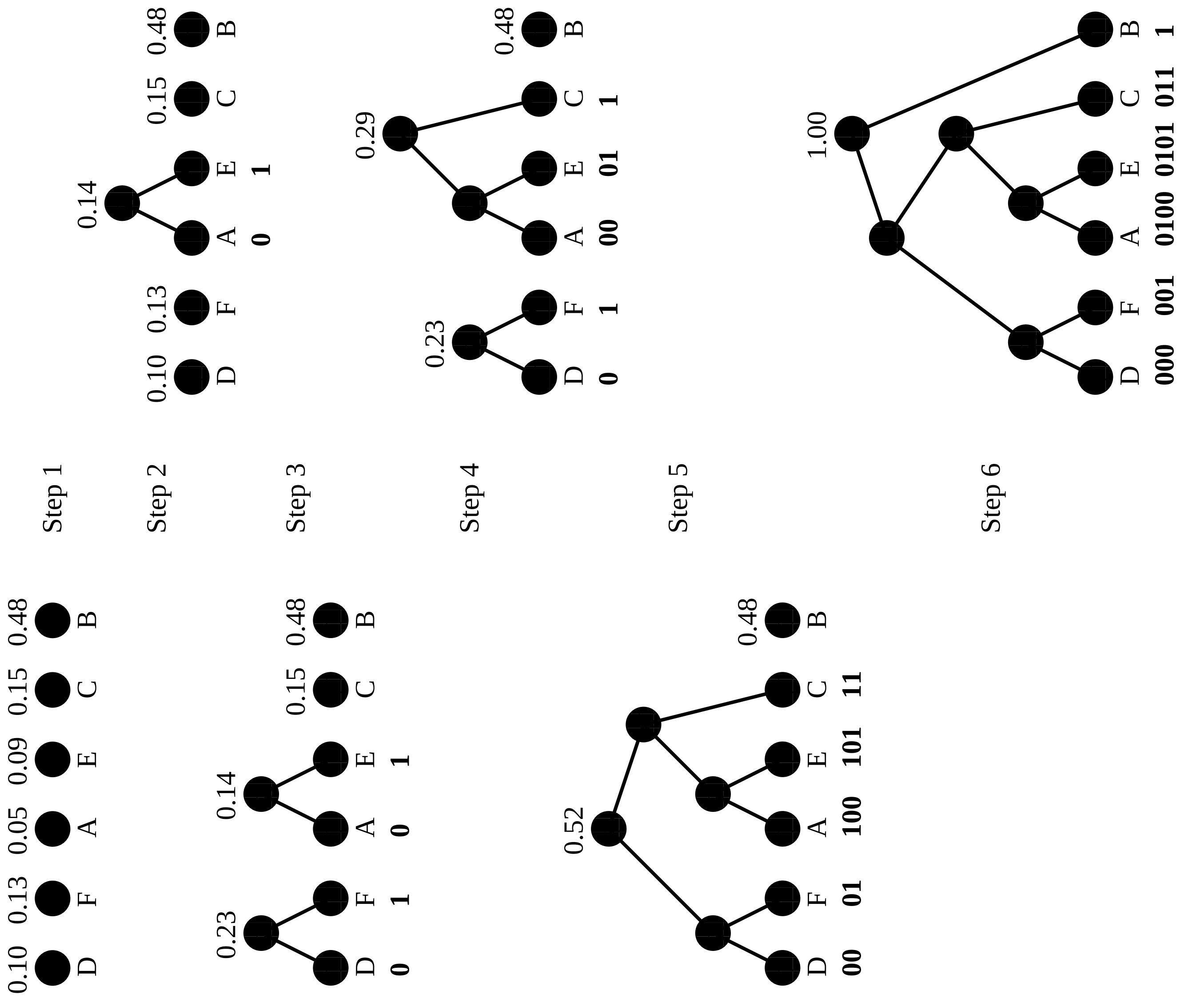
**Examples of transmission signals**



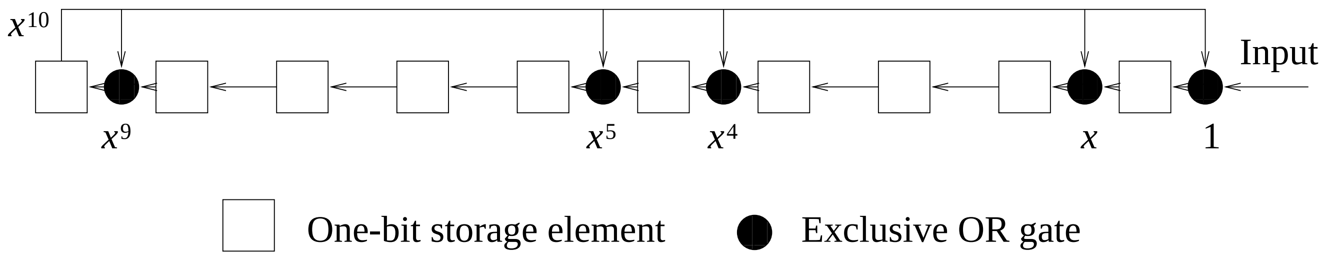

**Communication model involving information sharing**




**Coding and communication**

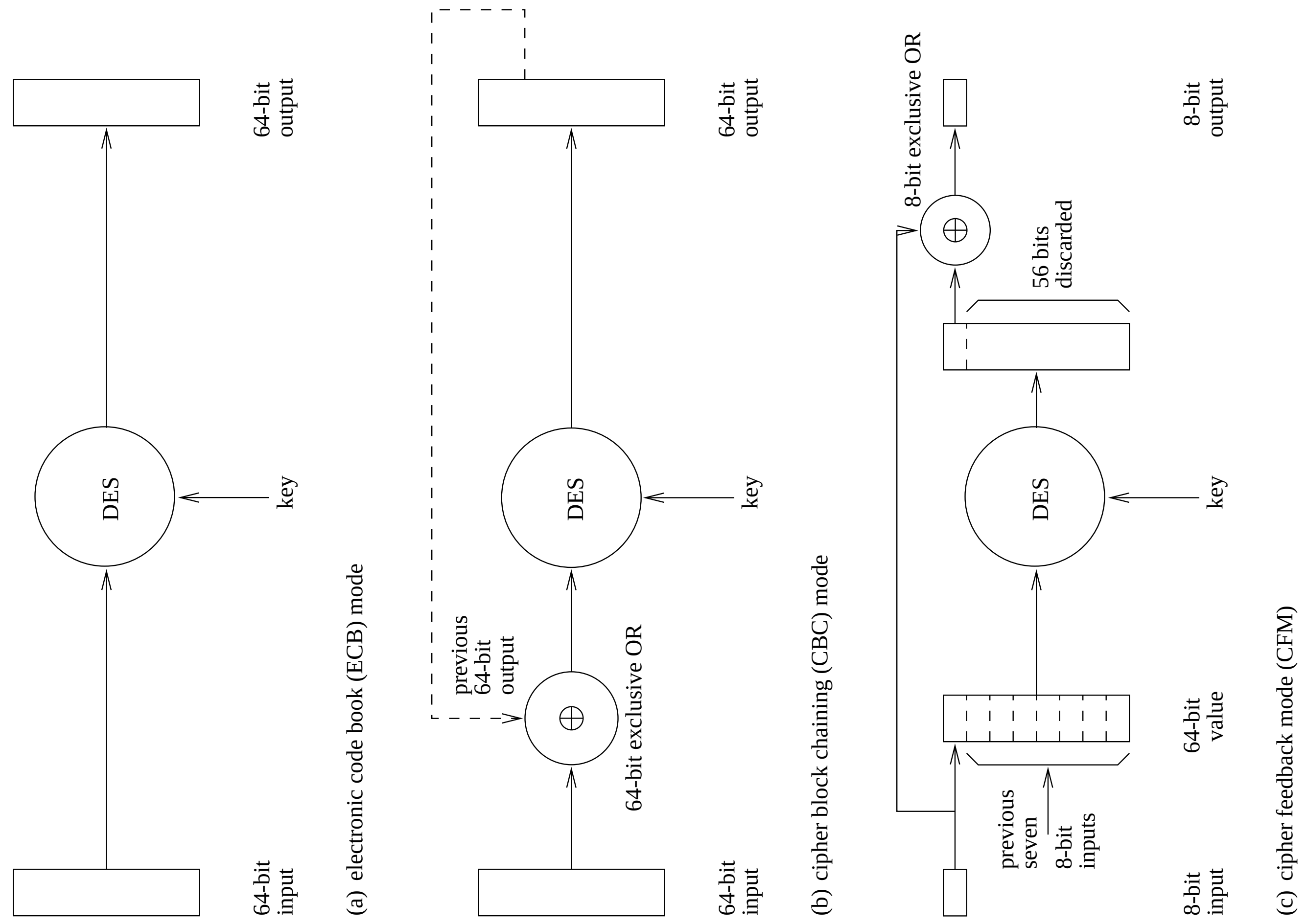


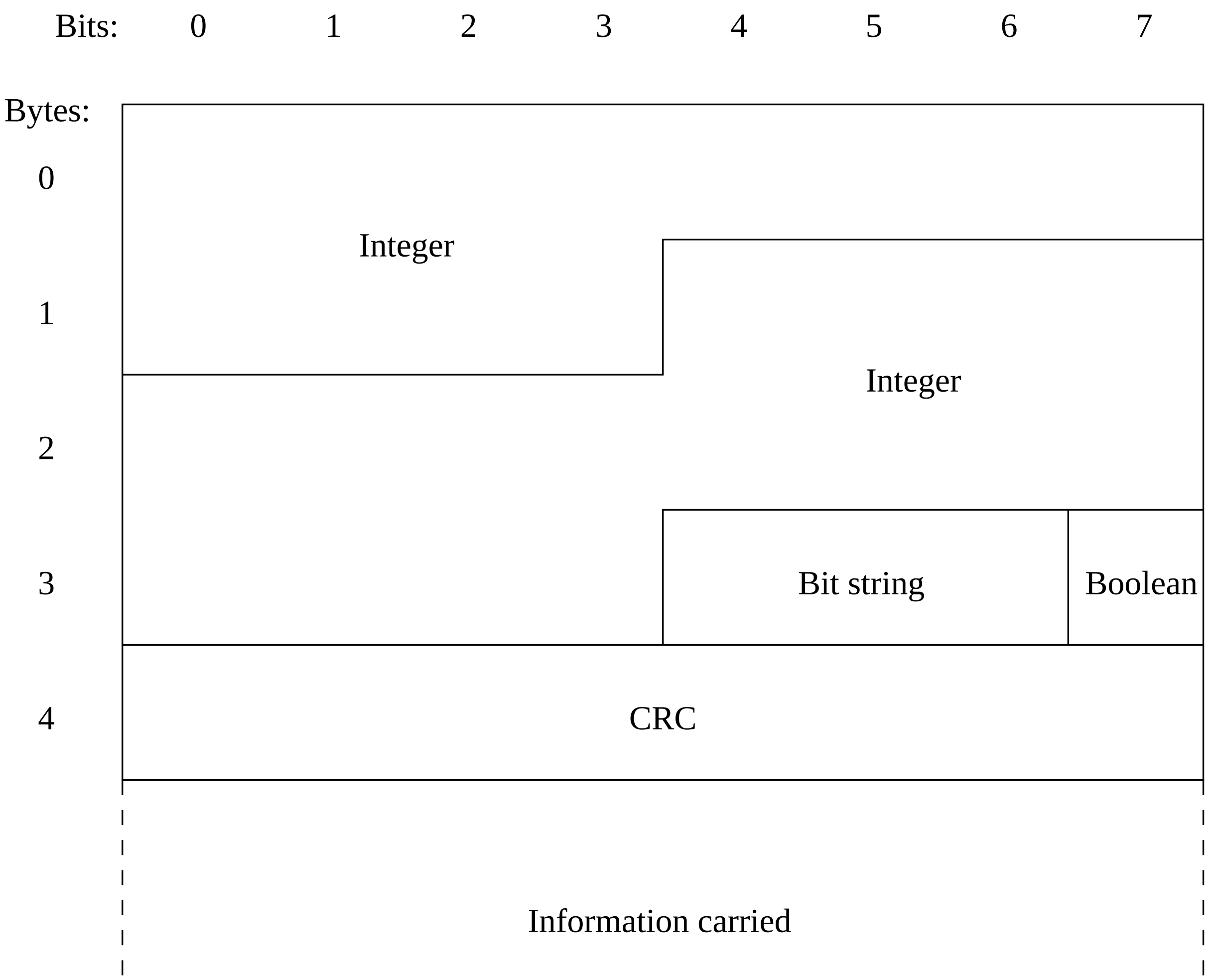

**Building a tree using Huffman's algorithm**



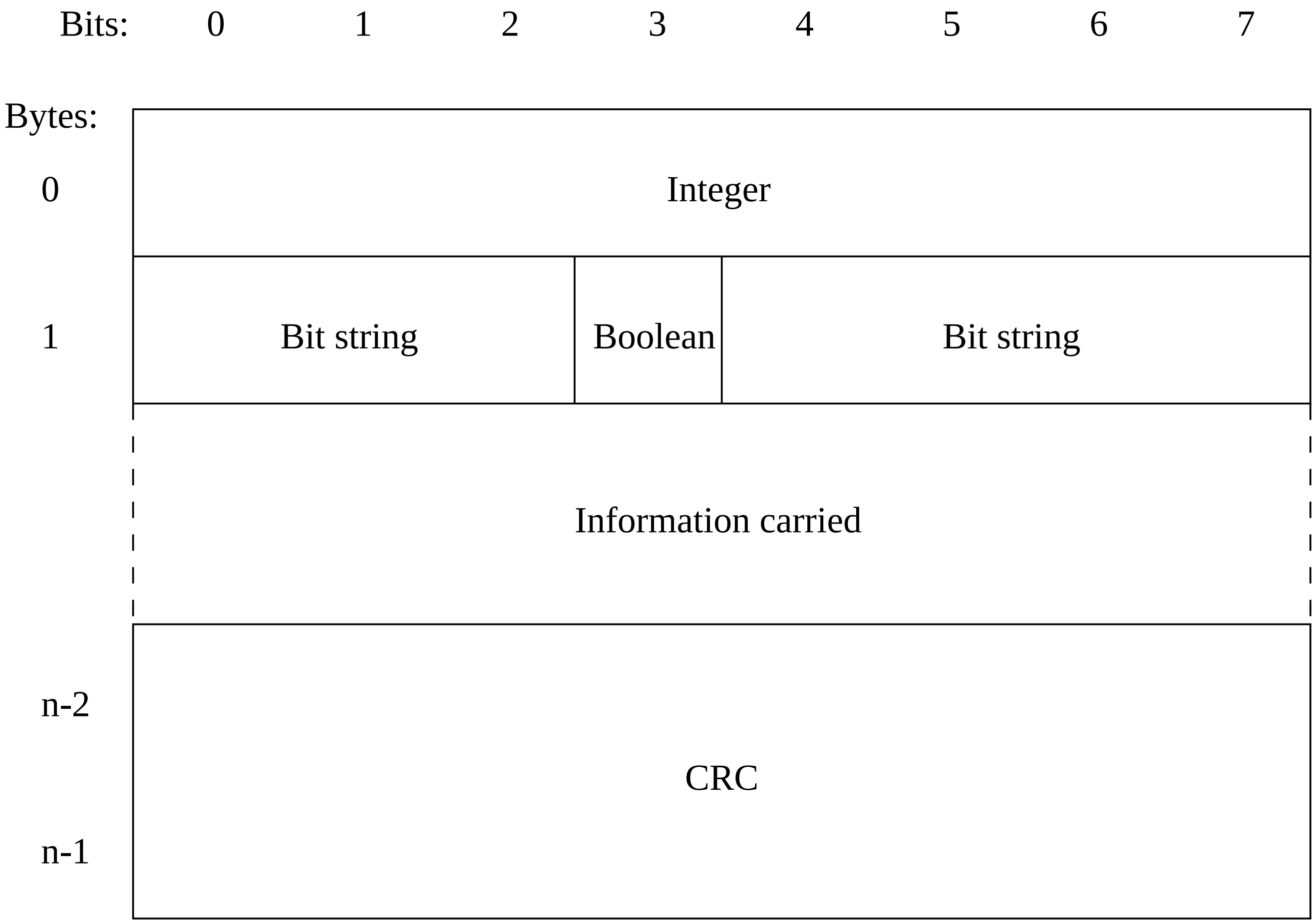

**Circuit that computes CRC using the CRC-10 generator**

# DES encryption modes

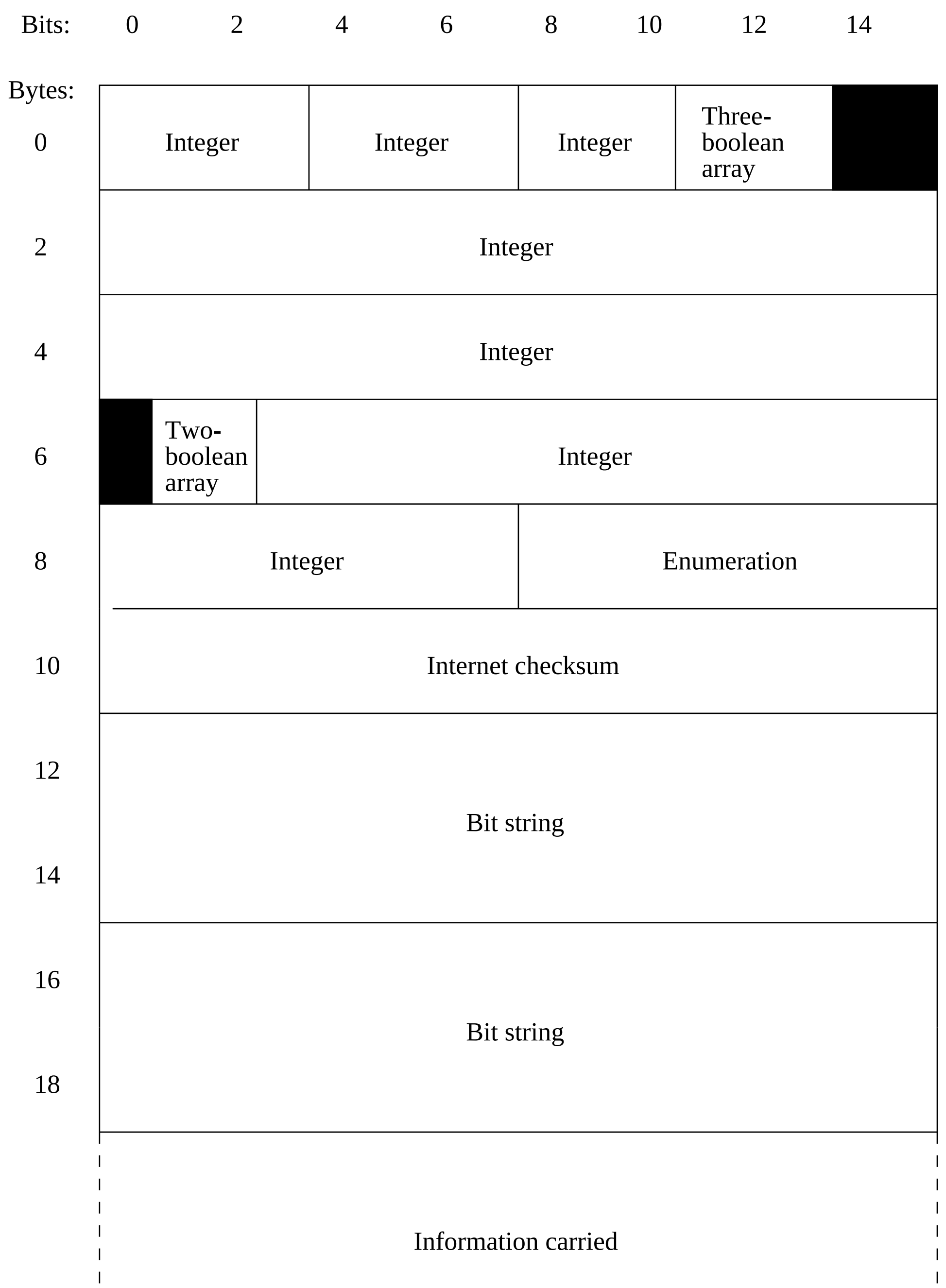




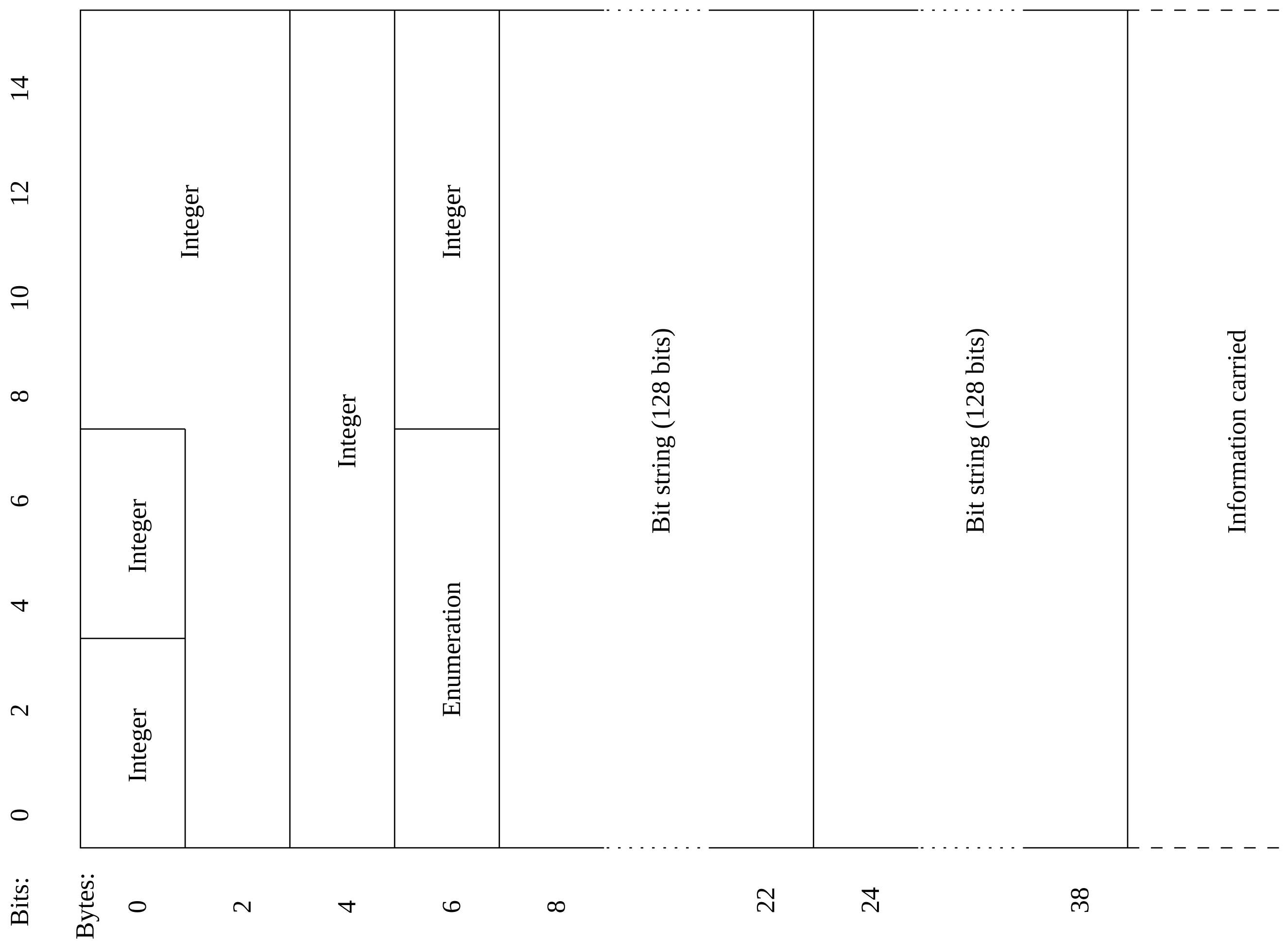

**Format of ATM ‘cell’**



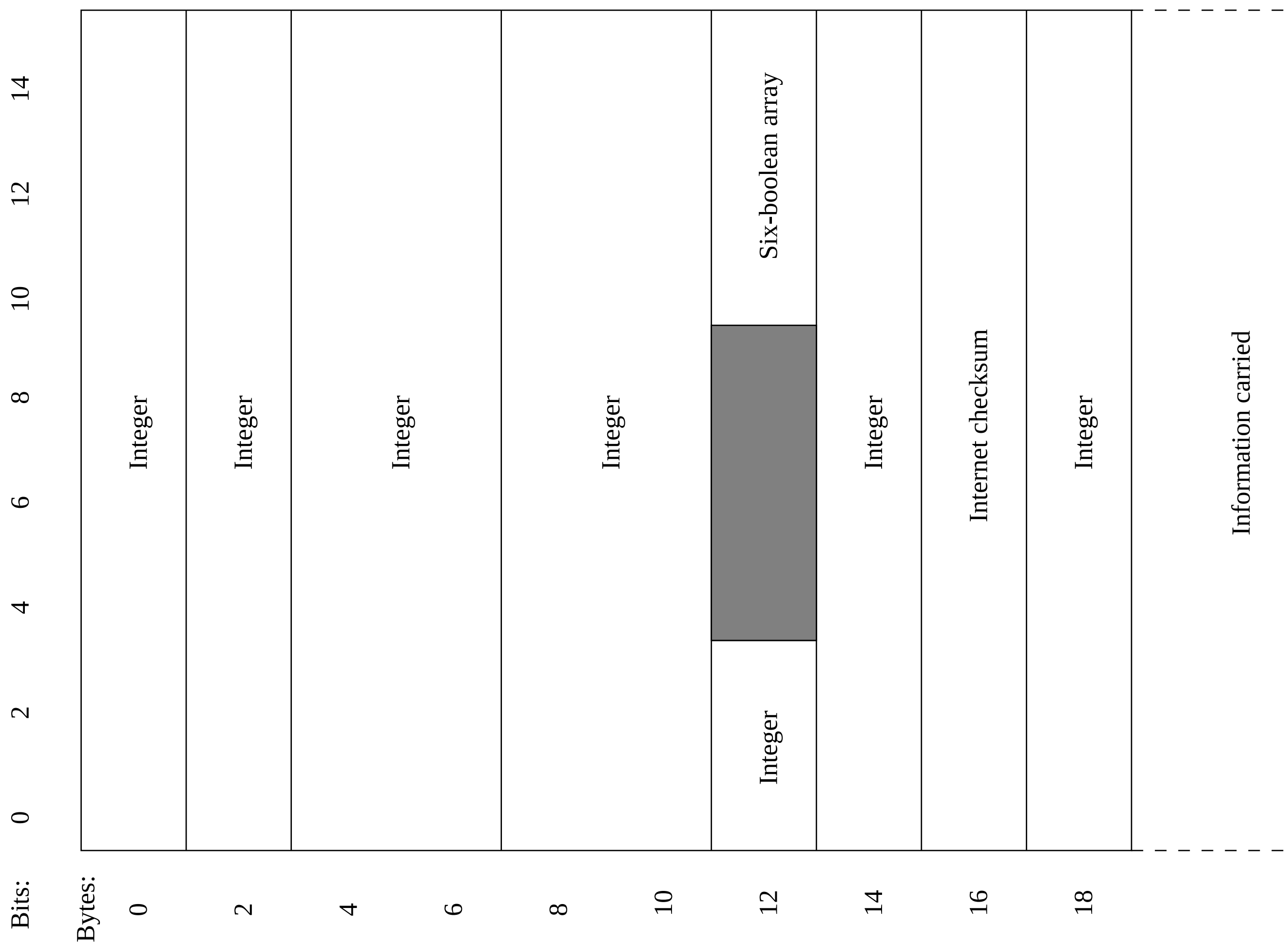

**Format of HDLC 'frame'**



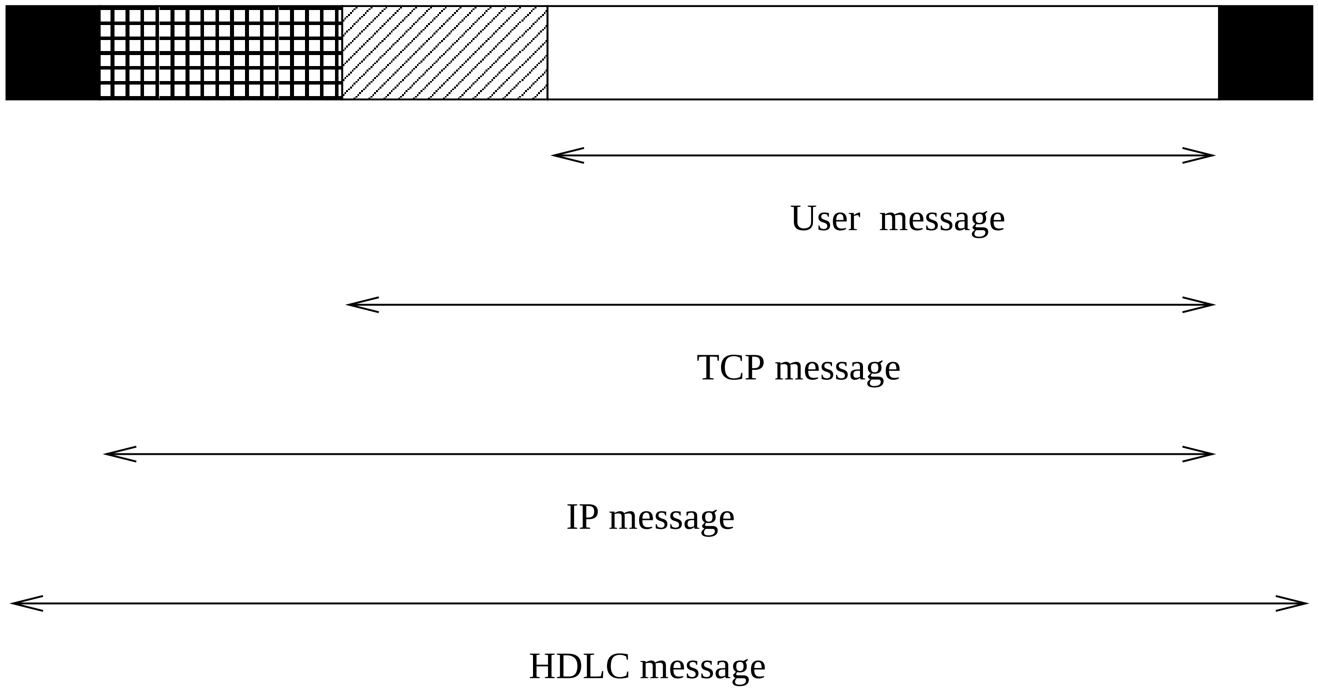

**Format of traditional IP ‘datagram’**



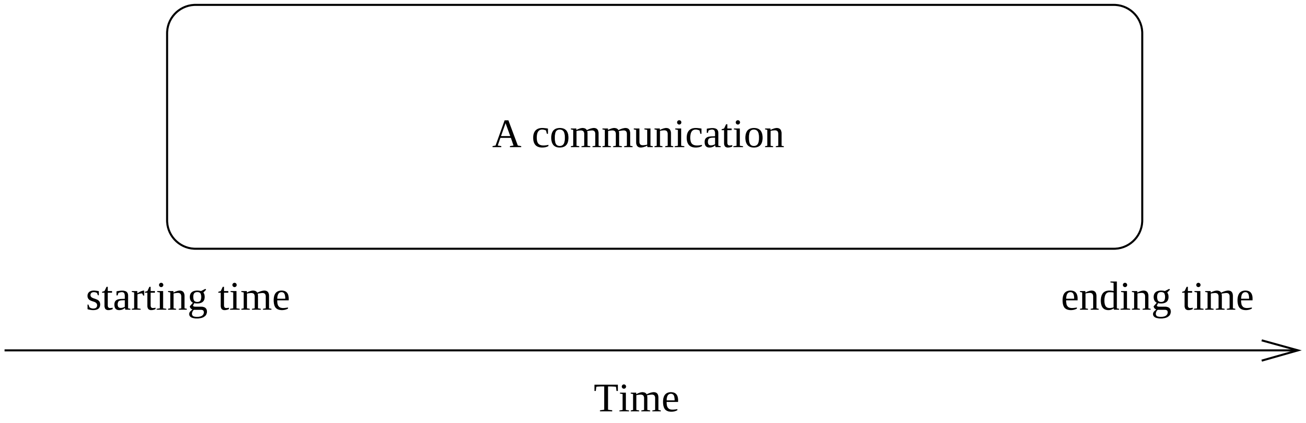

**Format of new IP 'datagram'**



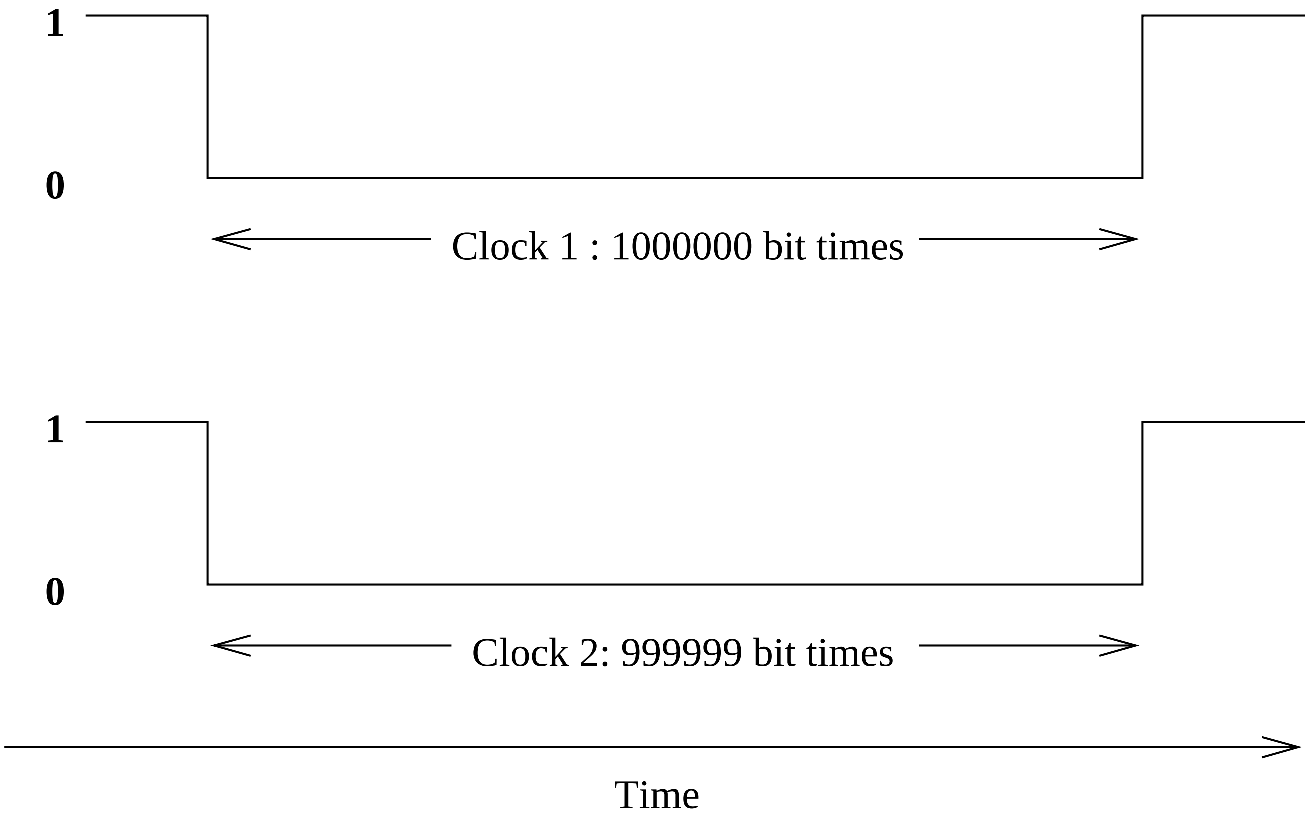

**Format of TCP component of TCP/IP 'segment'**



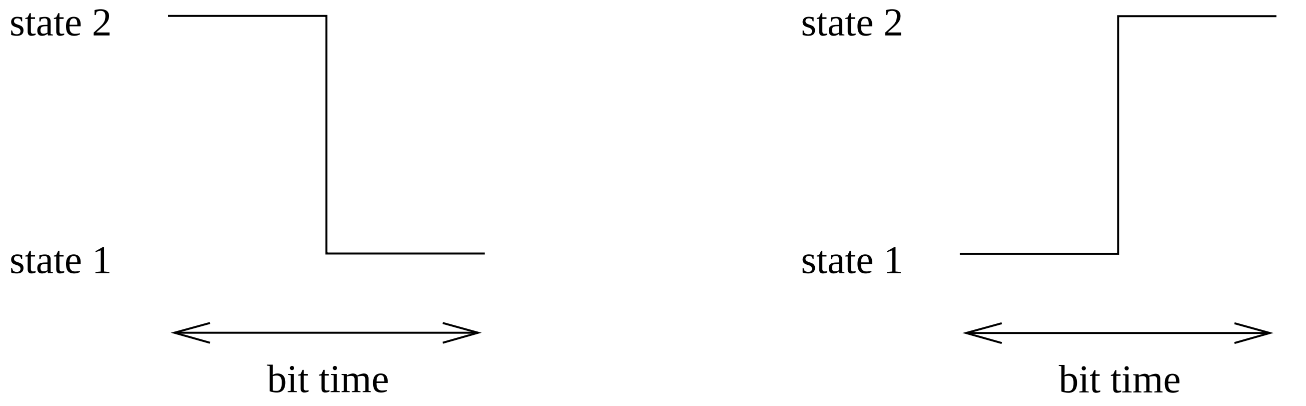

**Example of encapsulation of messages**




**Time period of a communication**



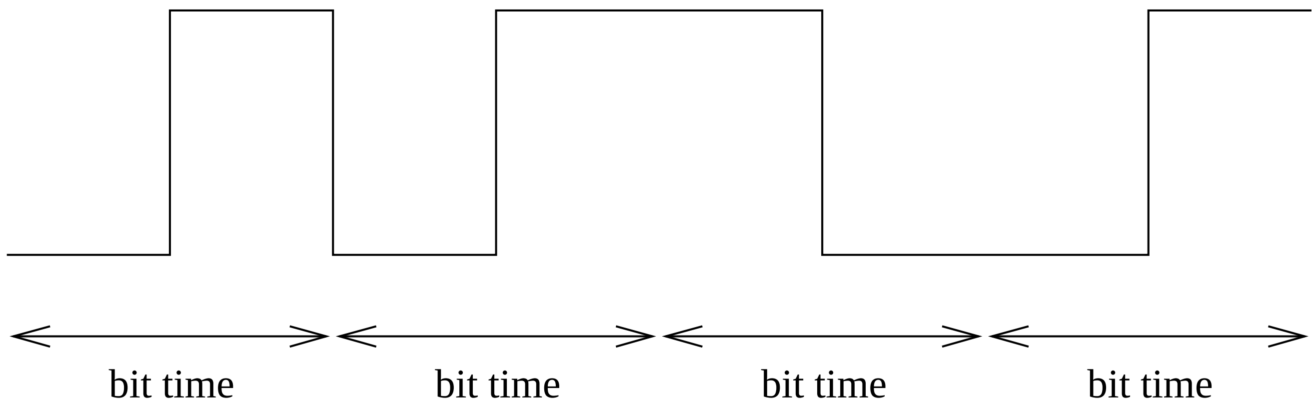

**Time drift between two independent clocks**



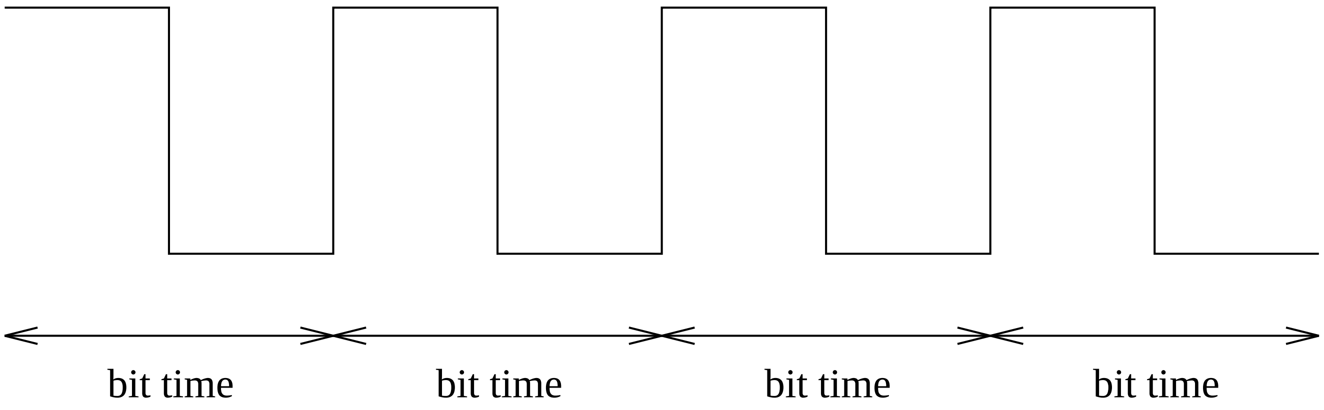

(a) zero bit value representation

*(b)* one bit value representation

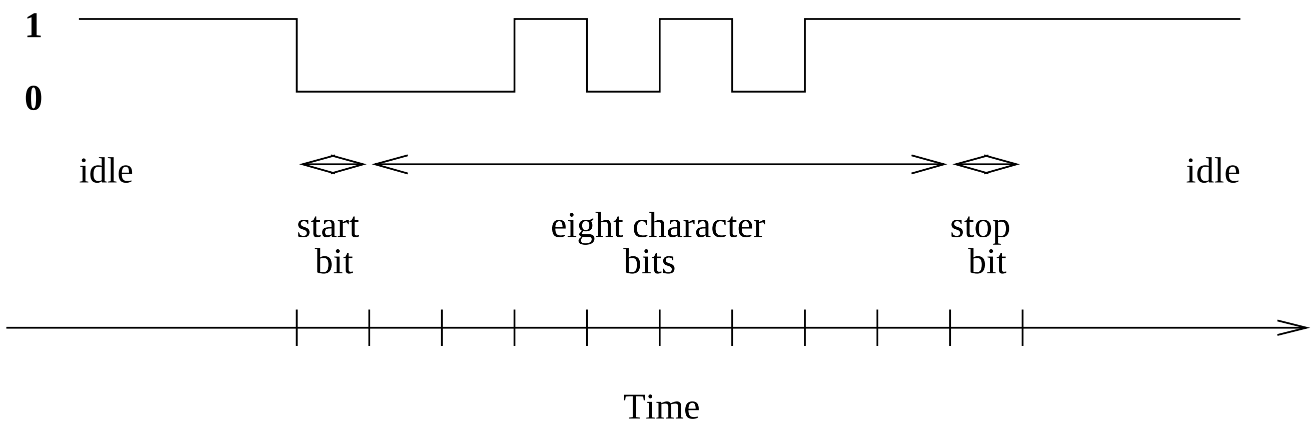
**Manchester encoding of the two bit values**



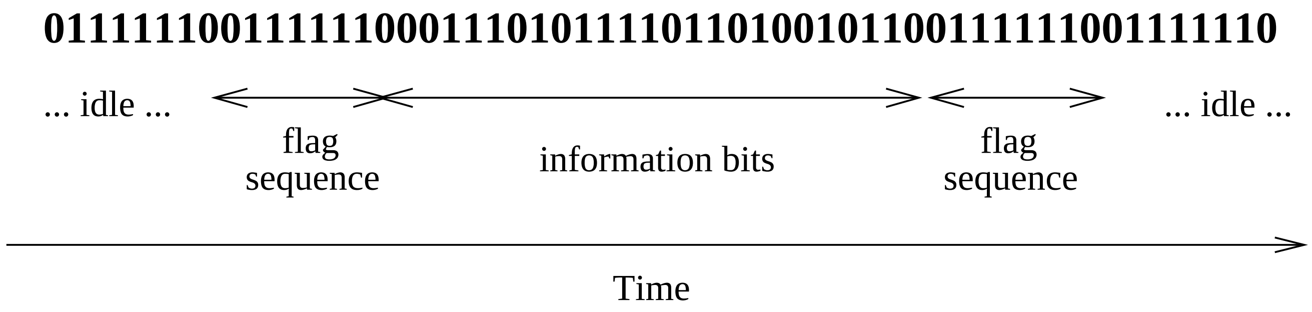

**Manchester encoding of 1101**




**Manchester encoding of four 0 bit values**




**Asynchronous transmission of the character 00101011**




**HDLC framing of 0011101011110110100101 10**

Transmitted sequence:

**010111110011**

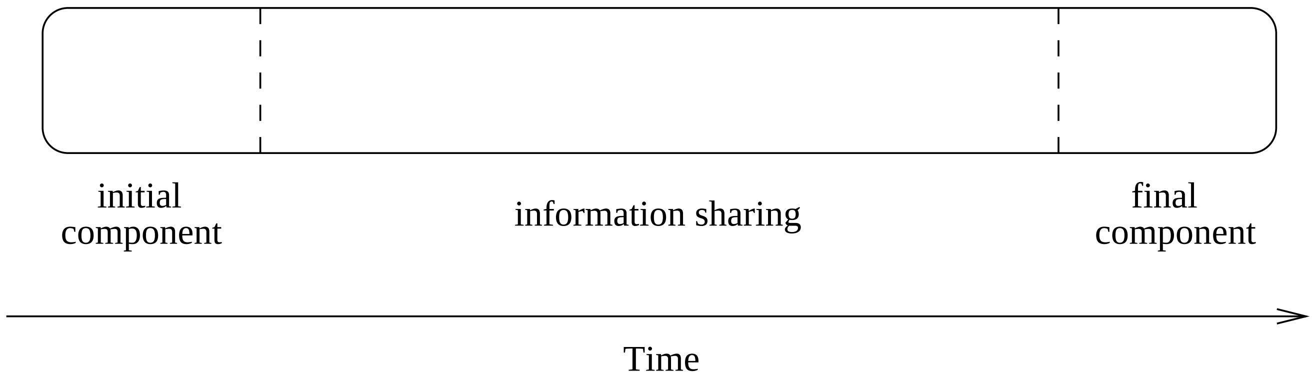
stuffed bit

Transmitted sequence:

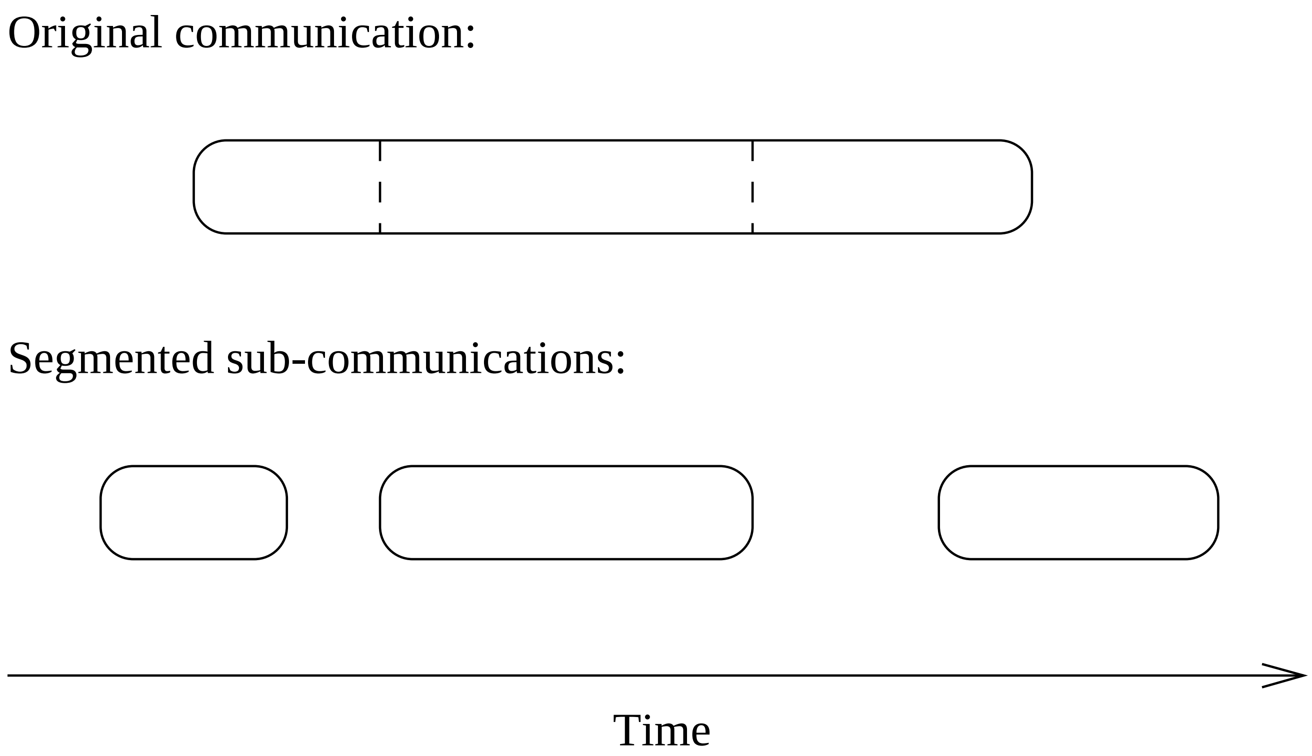
**100111110101**

stuffed bit

**Bit stuffing 01011111011 and 10011111101**

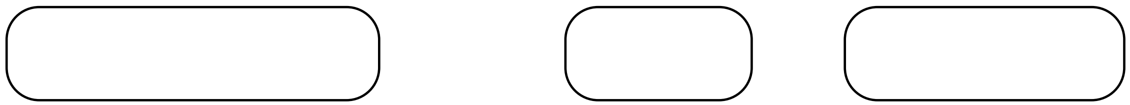



**Transaction or file transfer viewed over time**

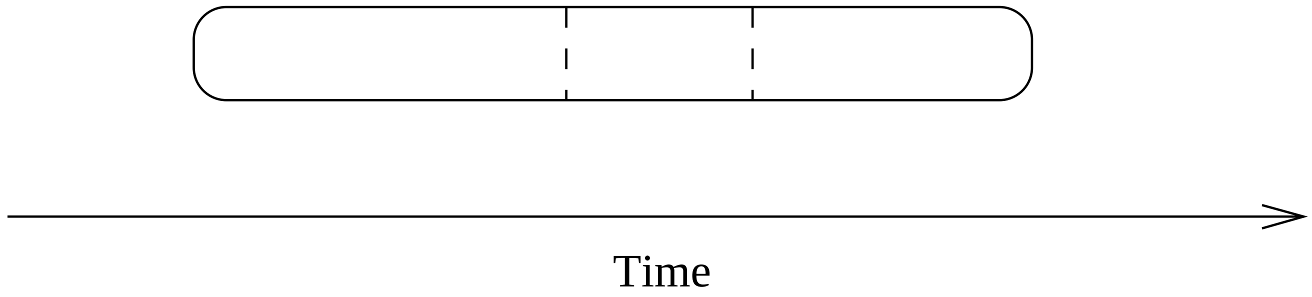



**Segmentation of a communication**

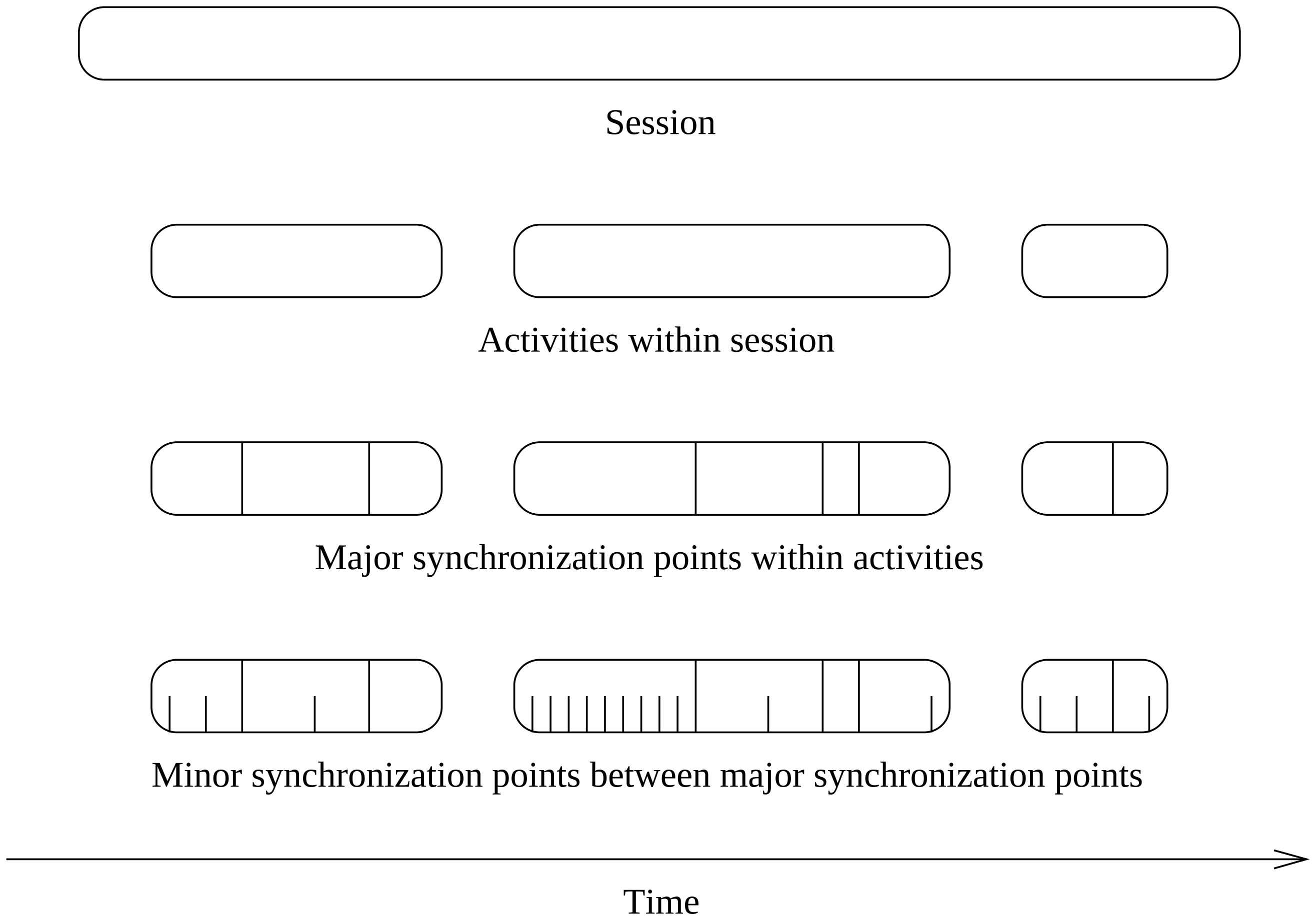
Original communications:



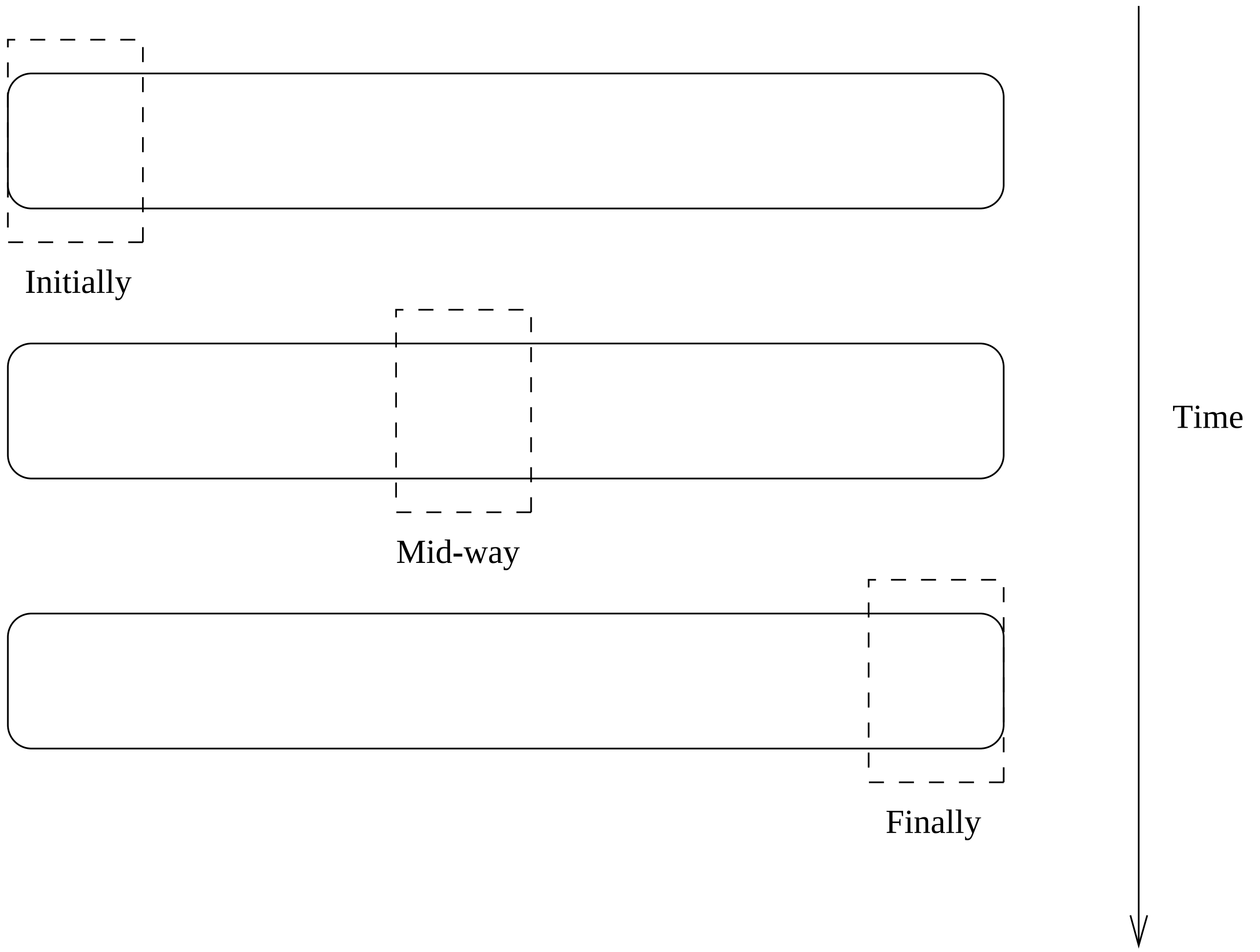
Concatenated super-communication:



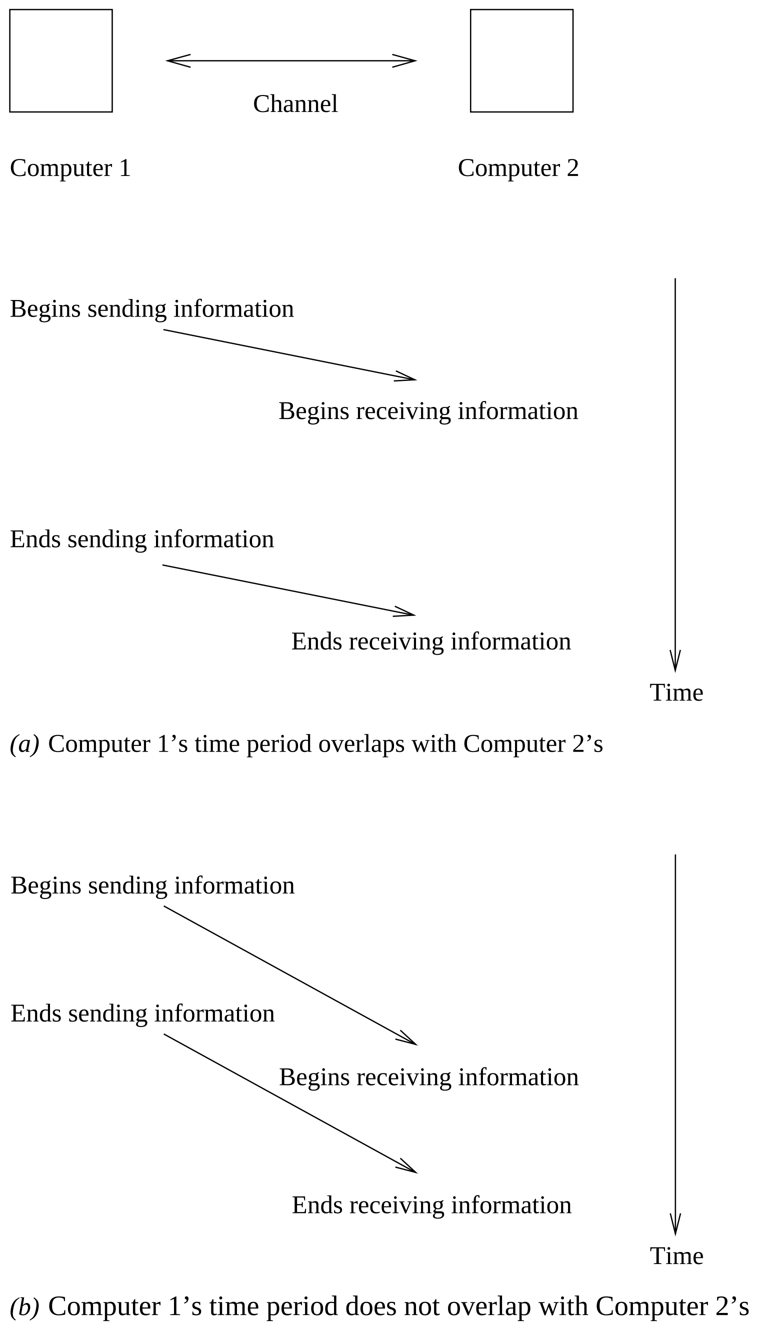

**Concatenation of communications**




**Structure of time periods in the ISO session service**



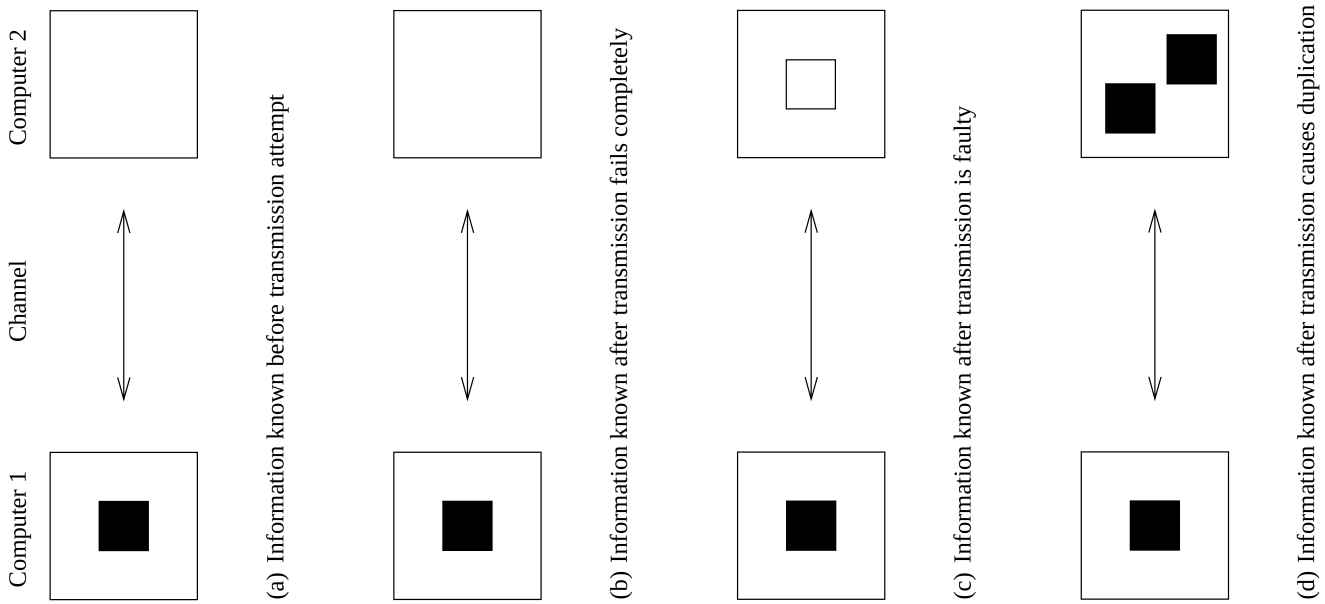

**Movement of sliding window over information**




# Communication involving an unsegmented time package

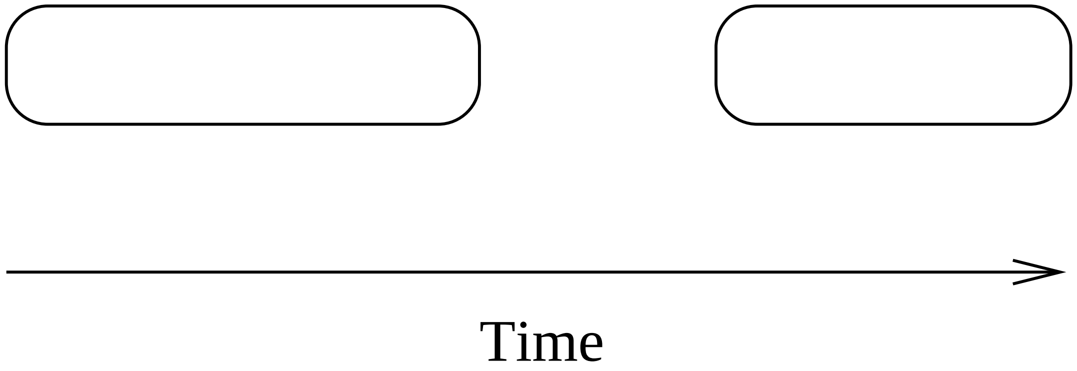
Gordon Brebner

# Possible failures for a connectionless service

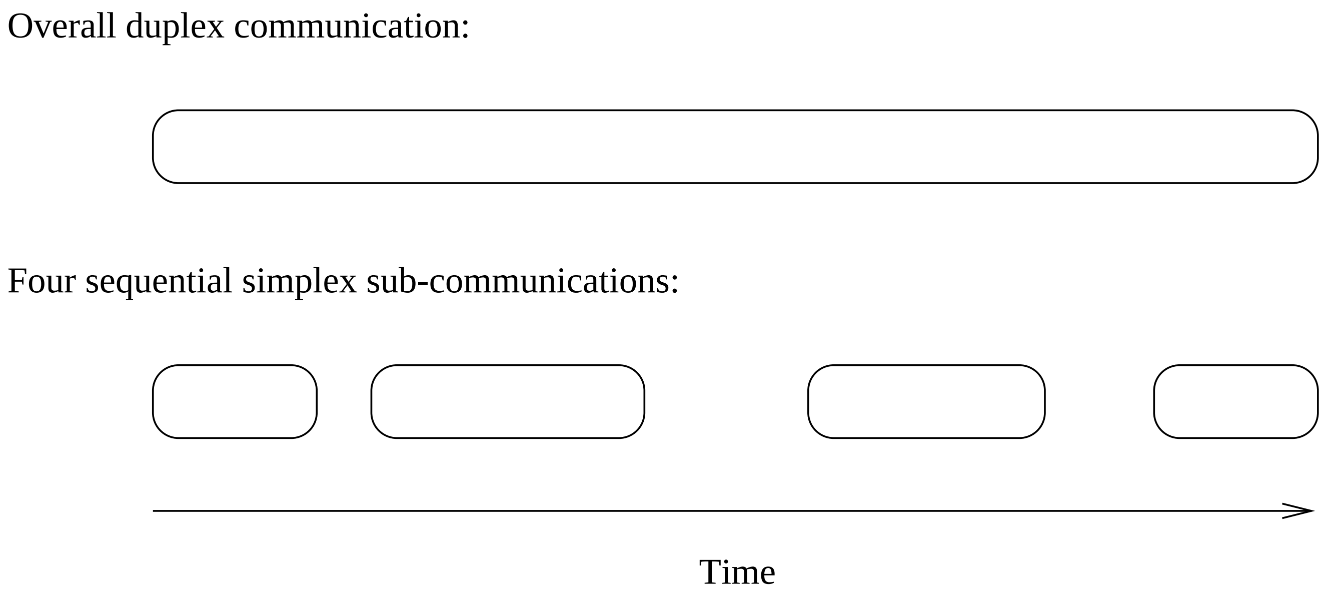


Overall bidirectional communication:

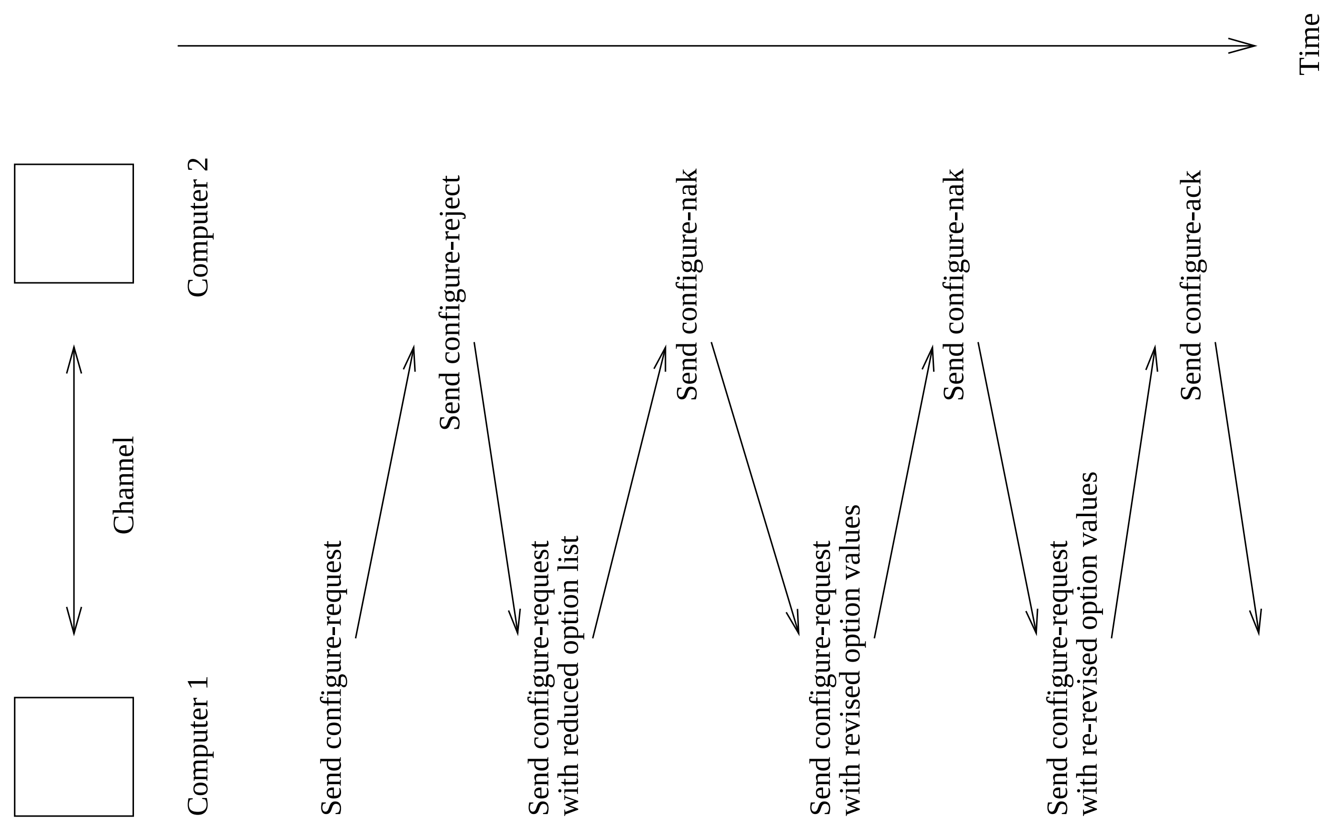
Two sequential unidirectional sub-communications:



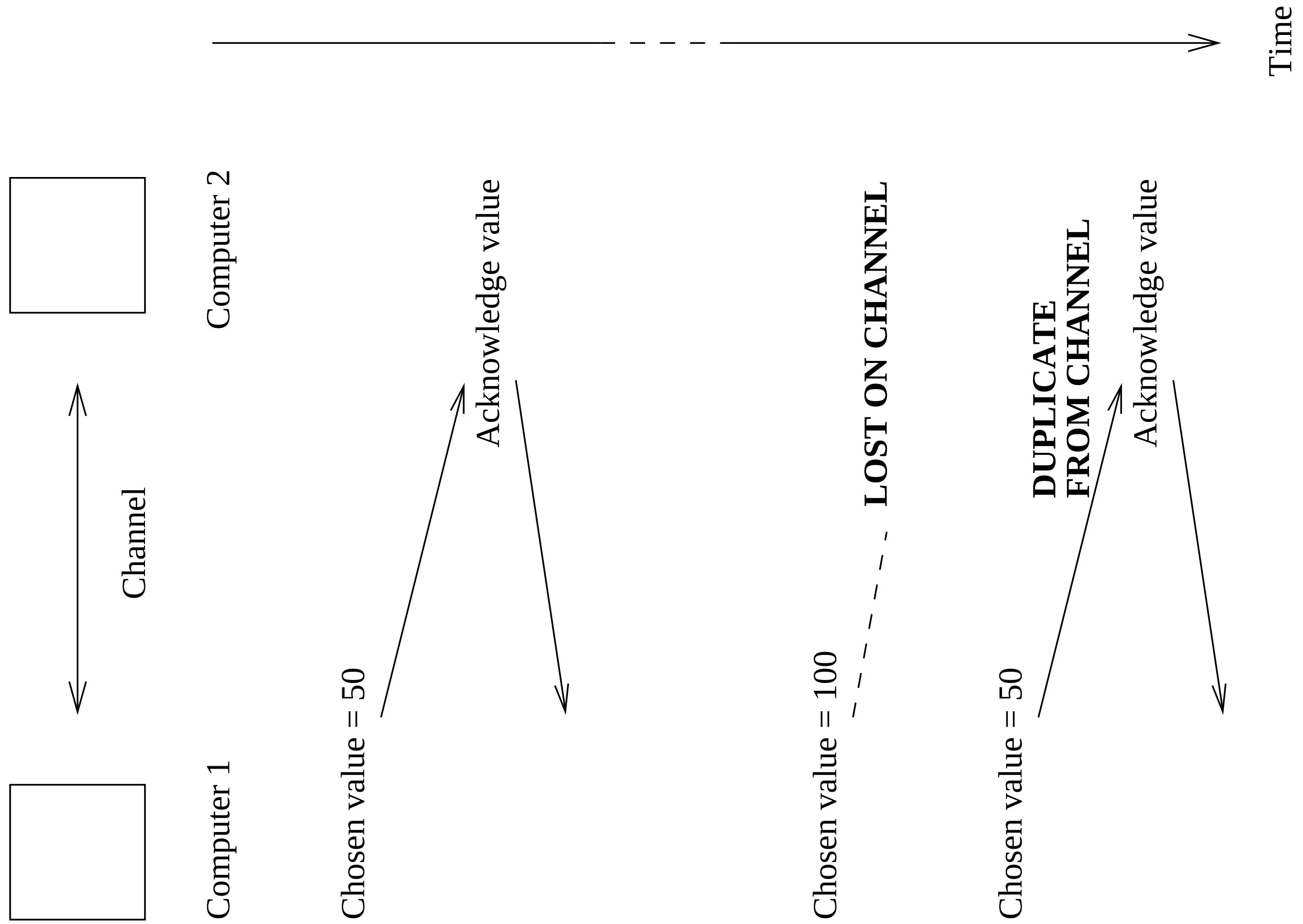

**Communication involving a simple handshake time package**



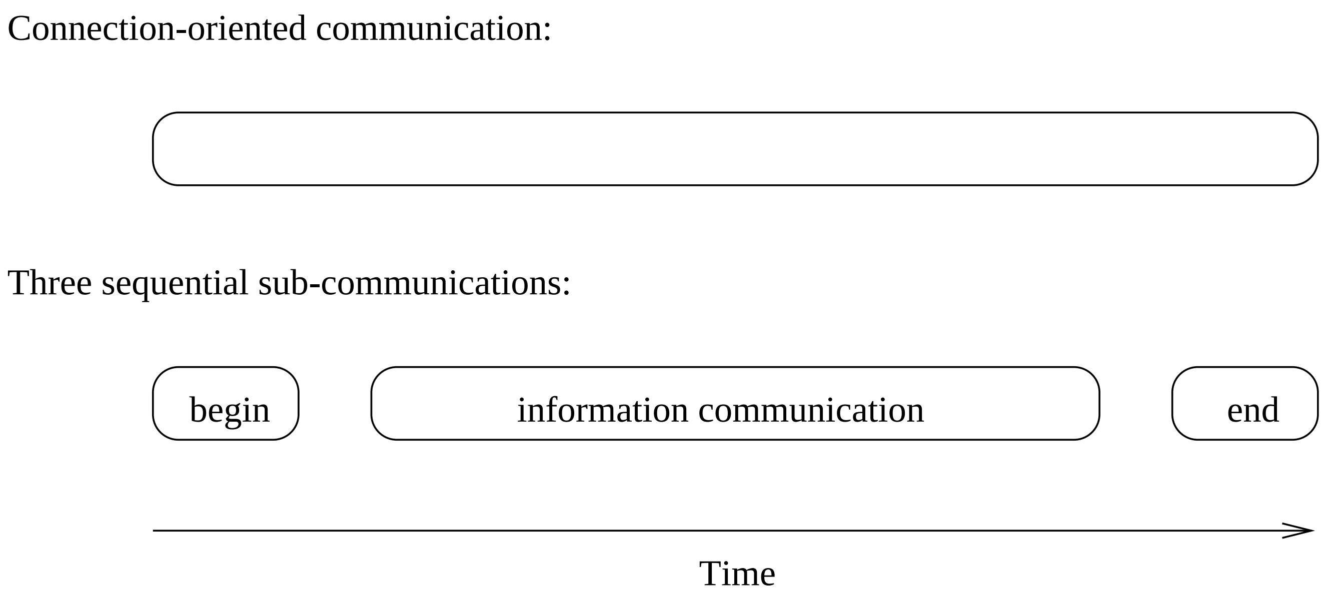

**Communication involving a four-stage handshake time package**



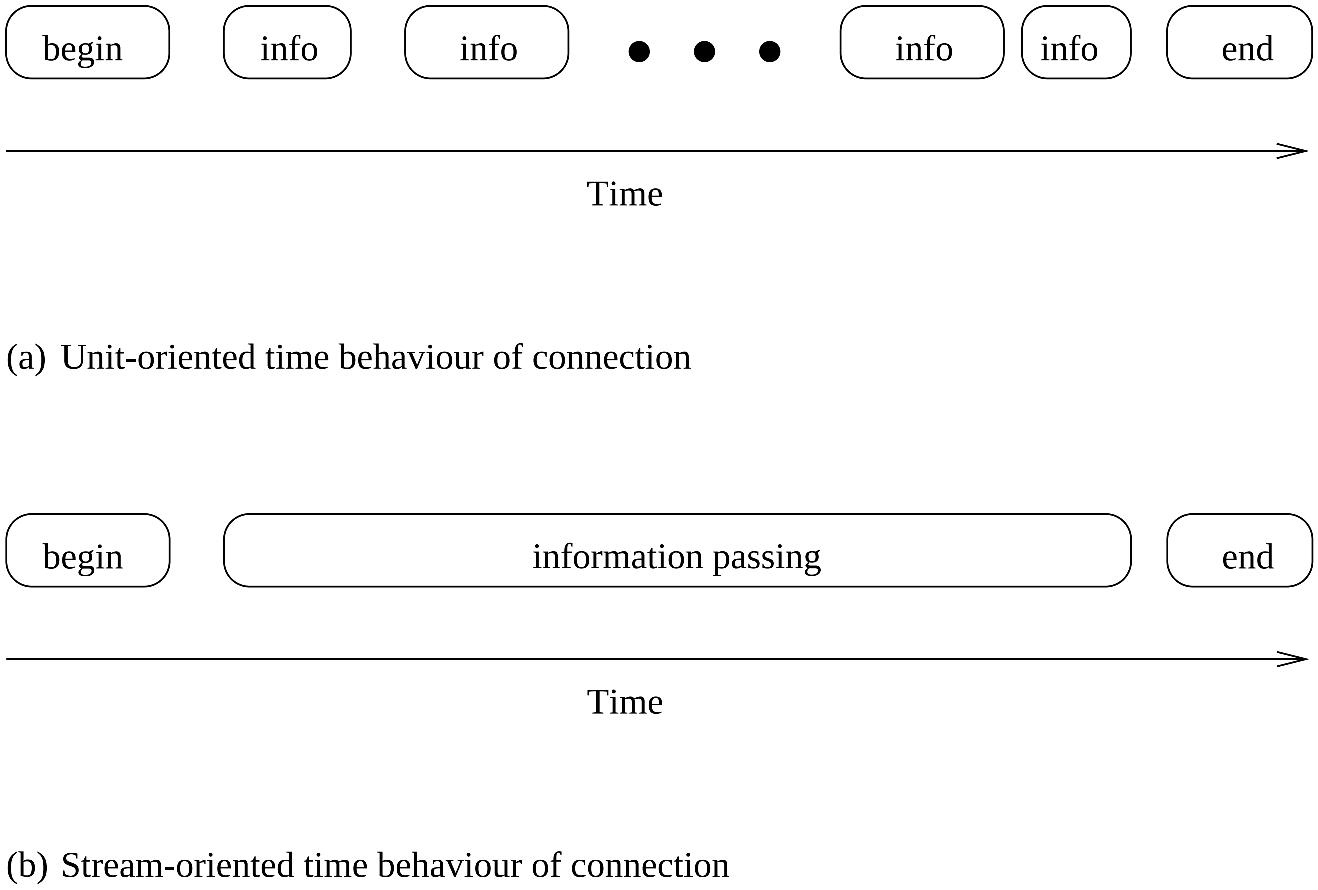

**Example of Link Control Protocol negotiation**



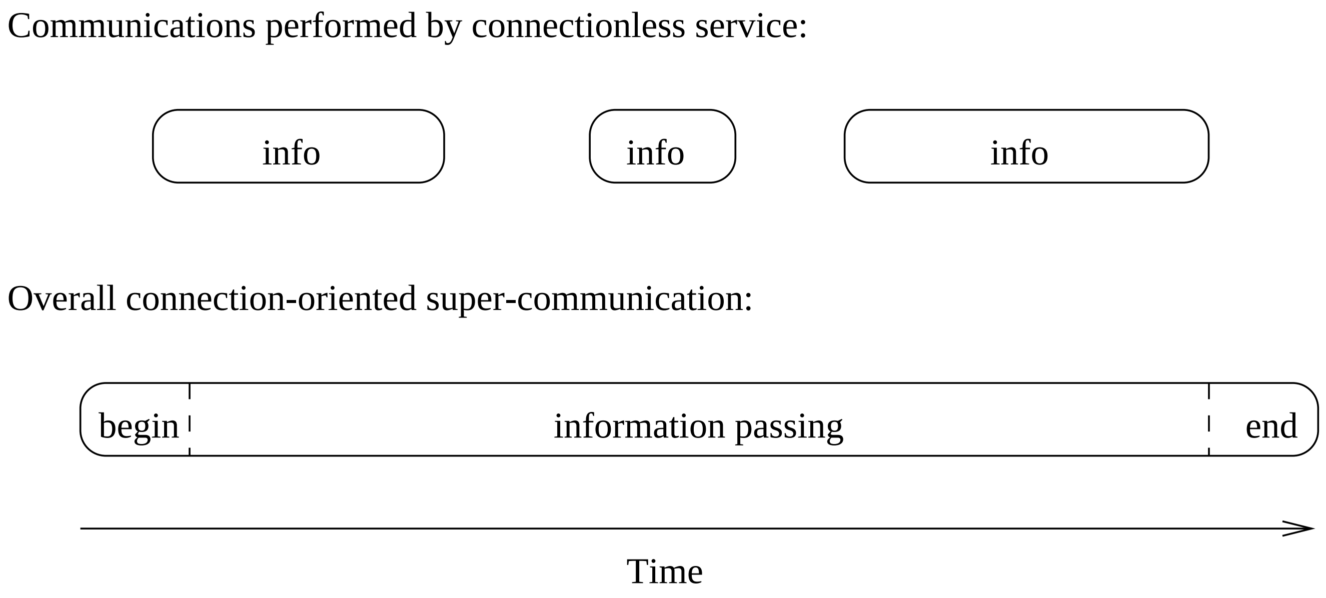

## Problem at beginning of TCP communication




**Communication involving a connection-oriented time package**

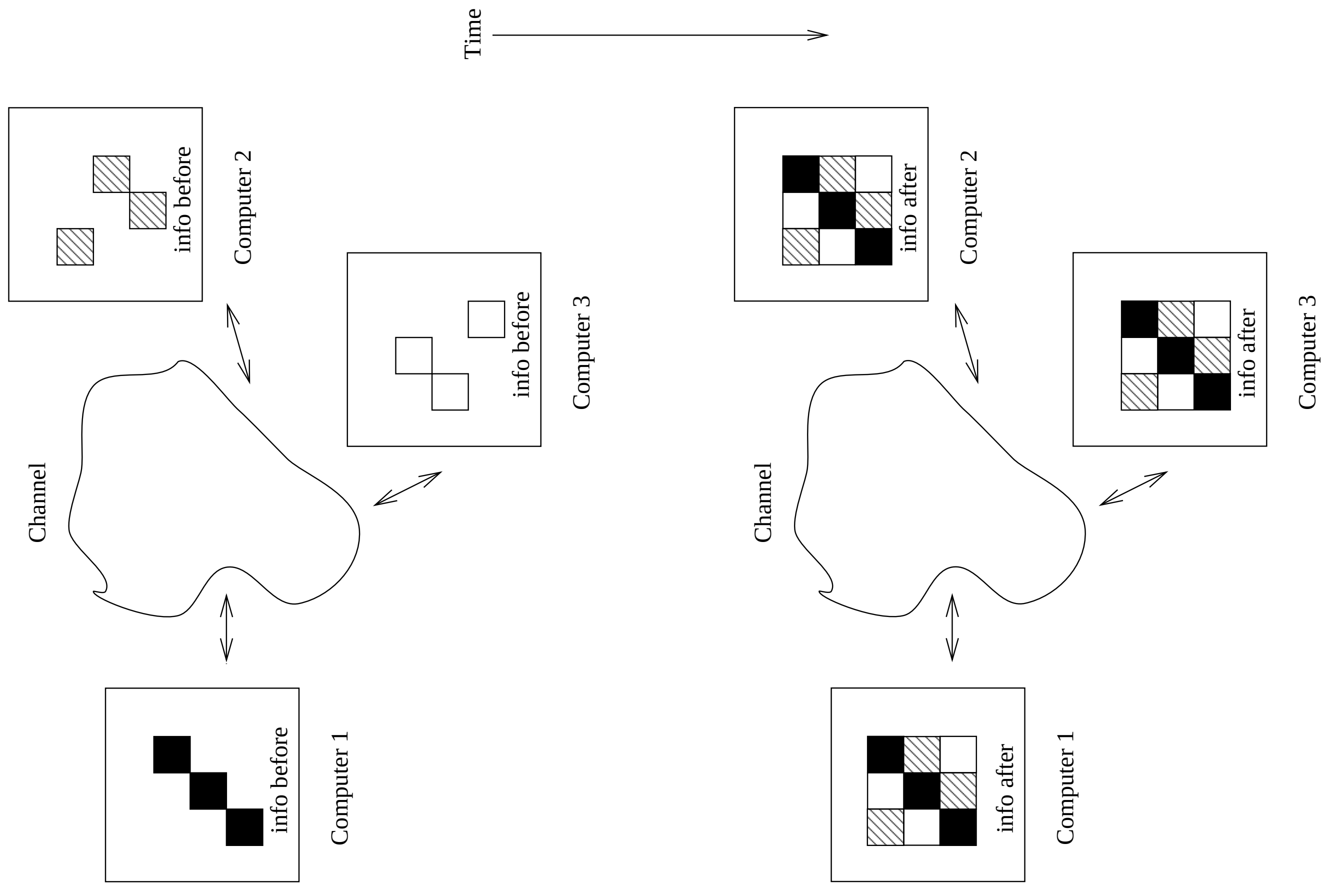



**Unit-oriented and stream-oriented time behaviour**



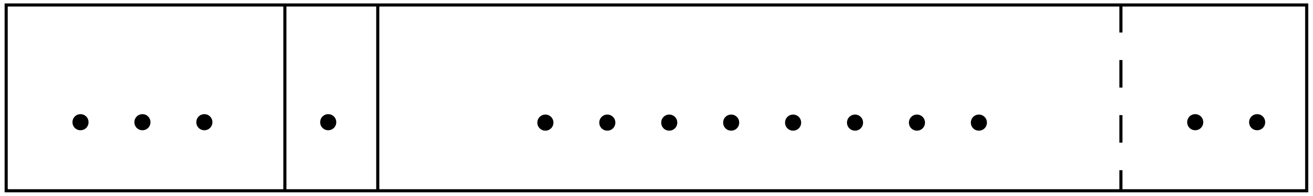

**Concatenation of connectionless communications**

# A communication

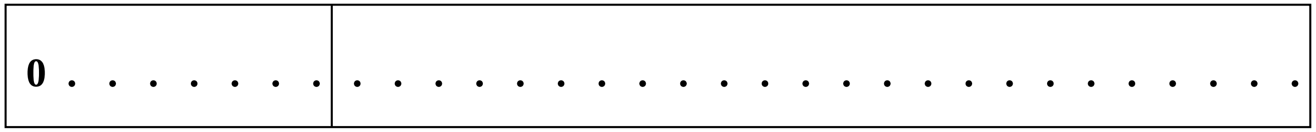


**00. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .**

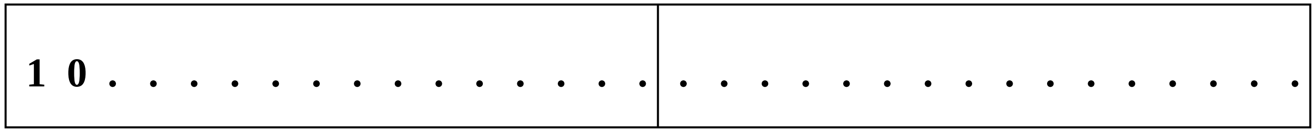
**IEEE standard 48-bit identifier**



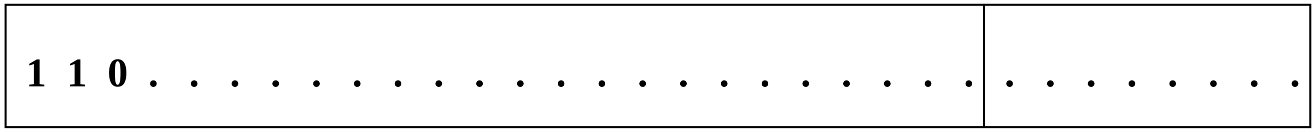
**Basic structure of an ITU-T X.121 standard identifier**




(a) Class A address format: 8 network and 24 computer address bits

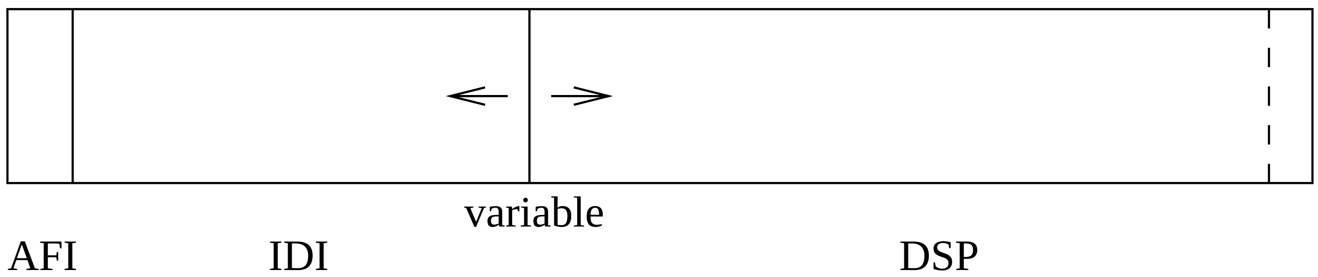



(b) Class B address format : 16 network and 16 computer address bits



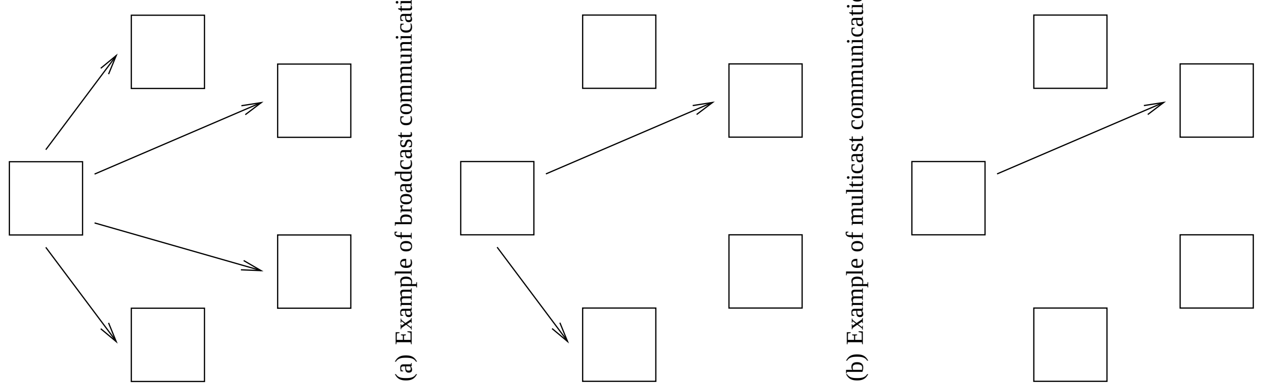

(c) Class C address format: 24 network and 8 computer address bits

**IP identifier structure**




**Basic structure of an ISO NSAP identifier**

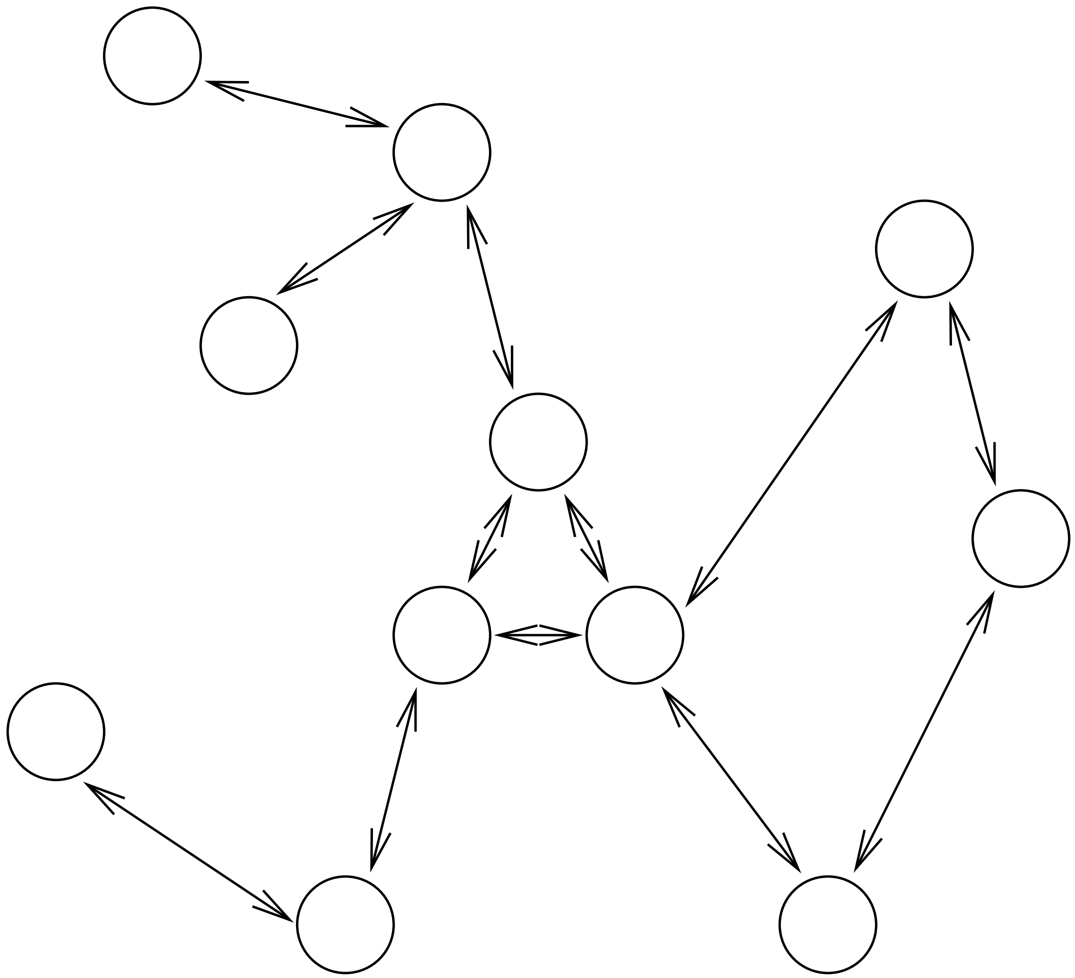
# Broadcast, multicast and unicast information flows



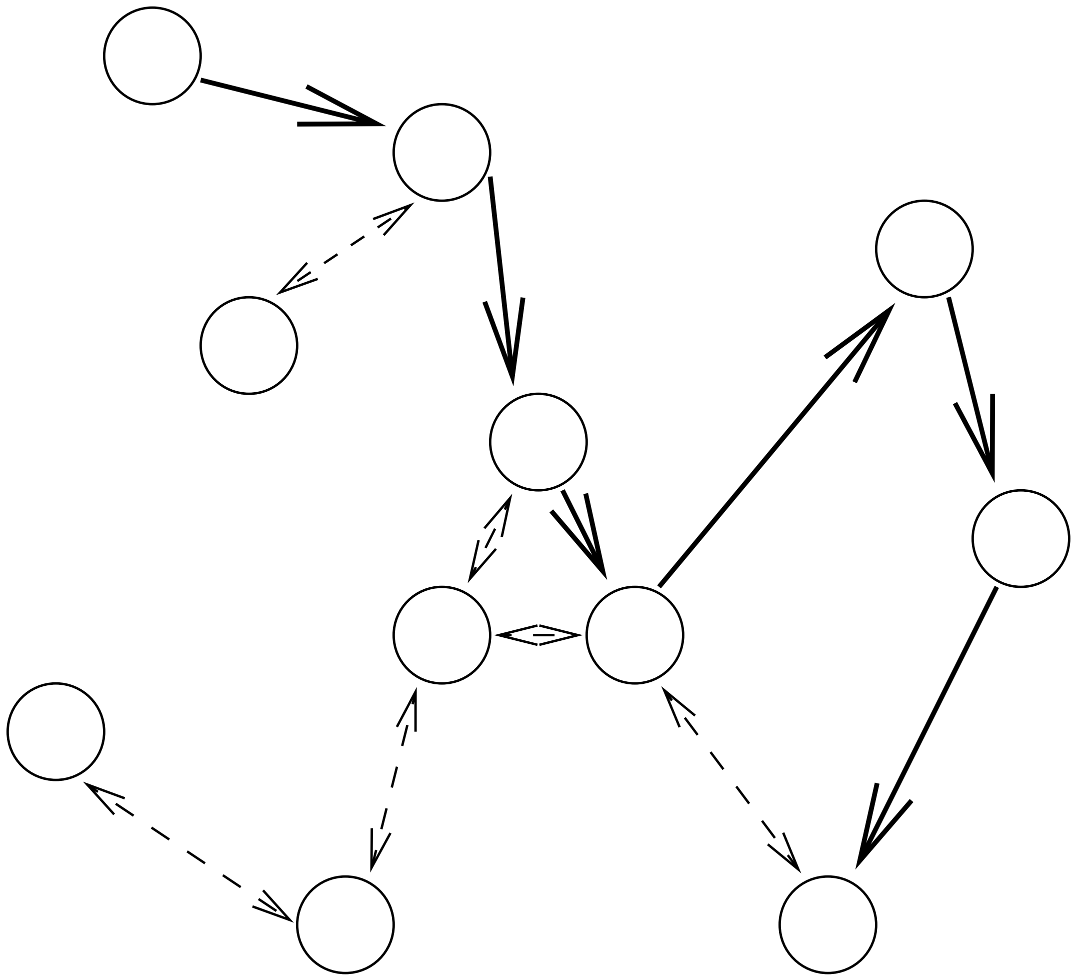
(a) Example of broadcast communication

(b) Example of multicast communication

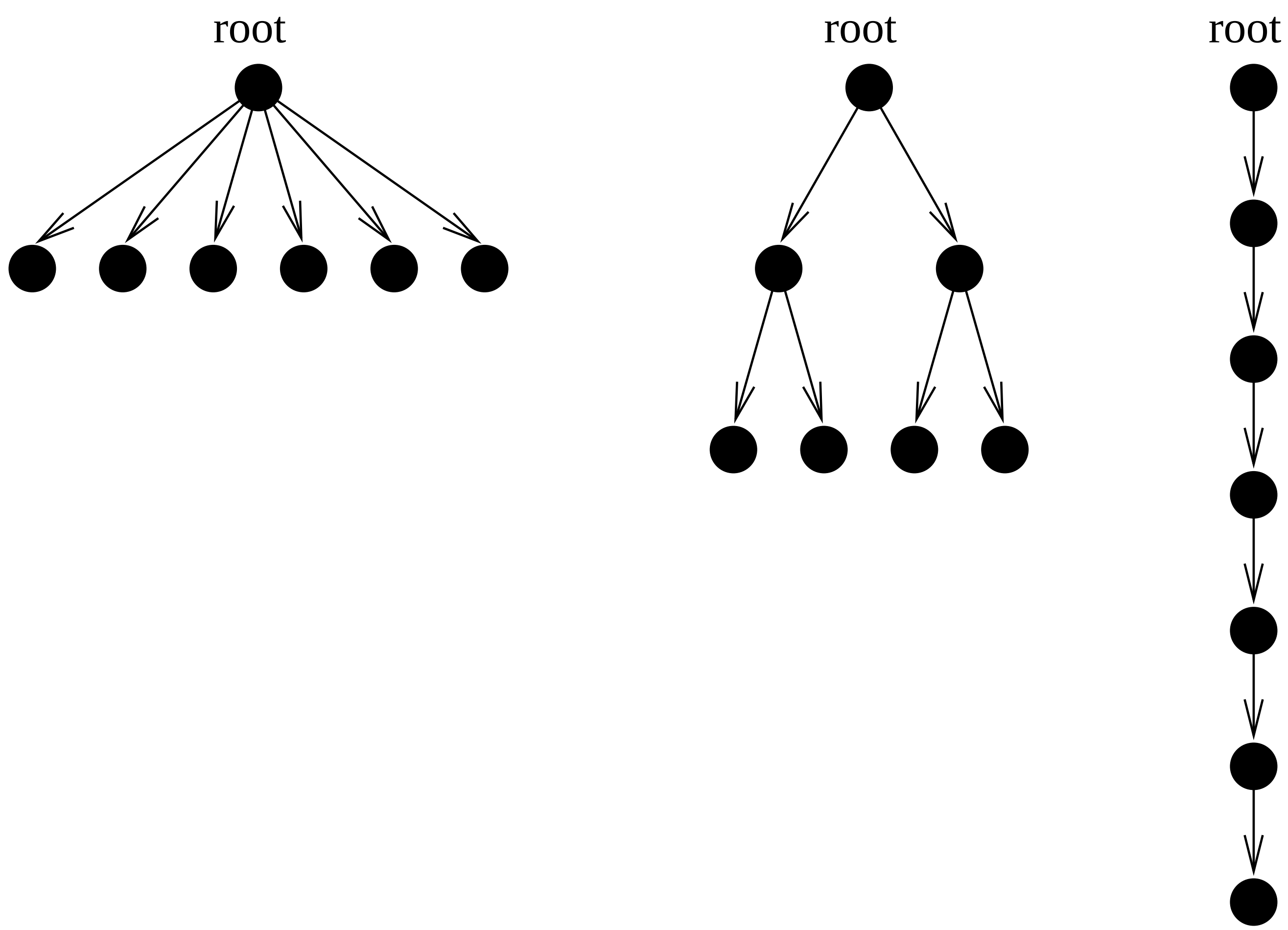
(c) Example of unicast communication



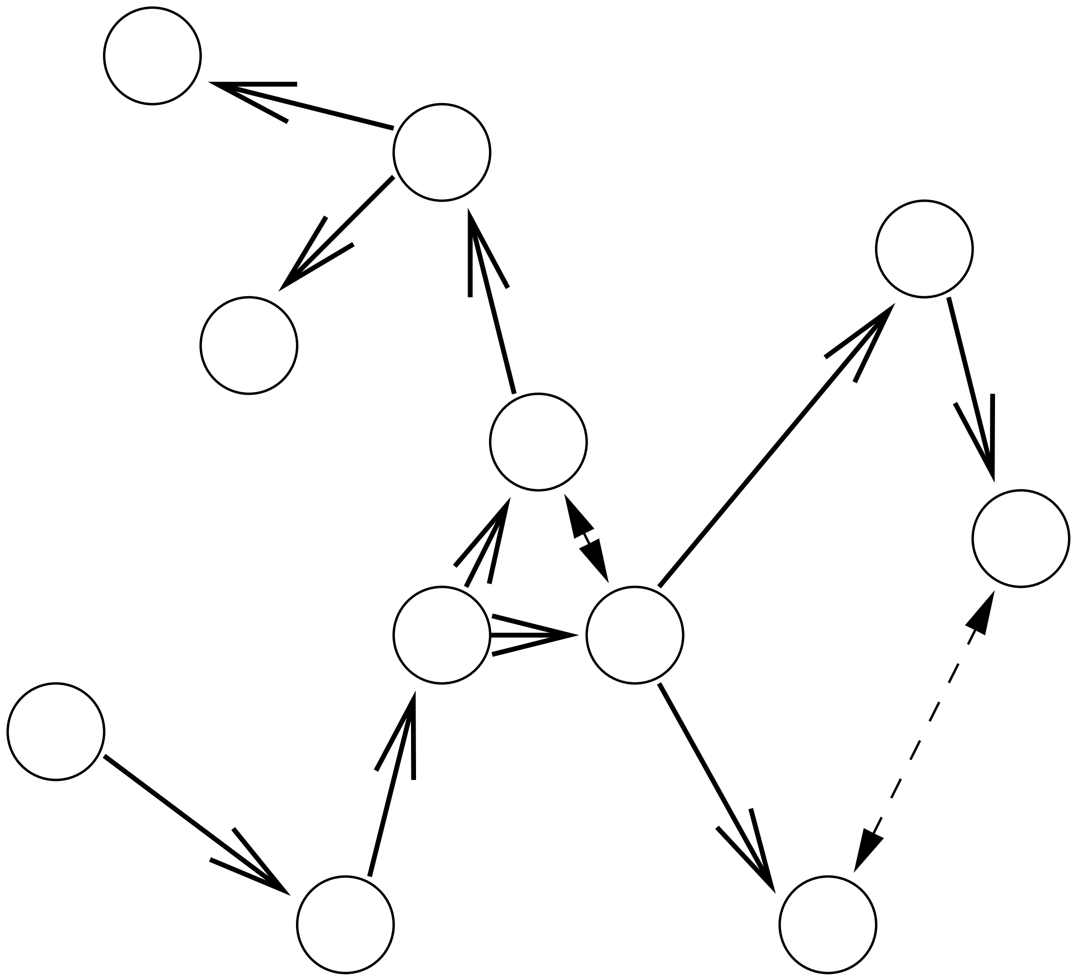
**Example graph representing network**



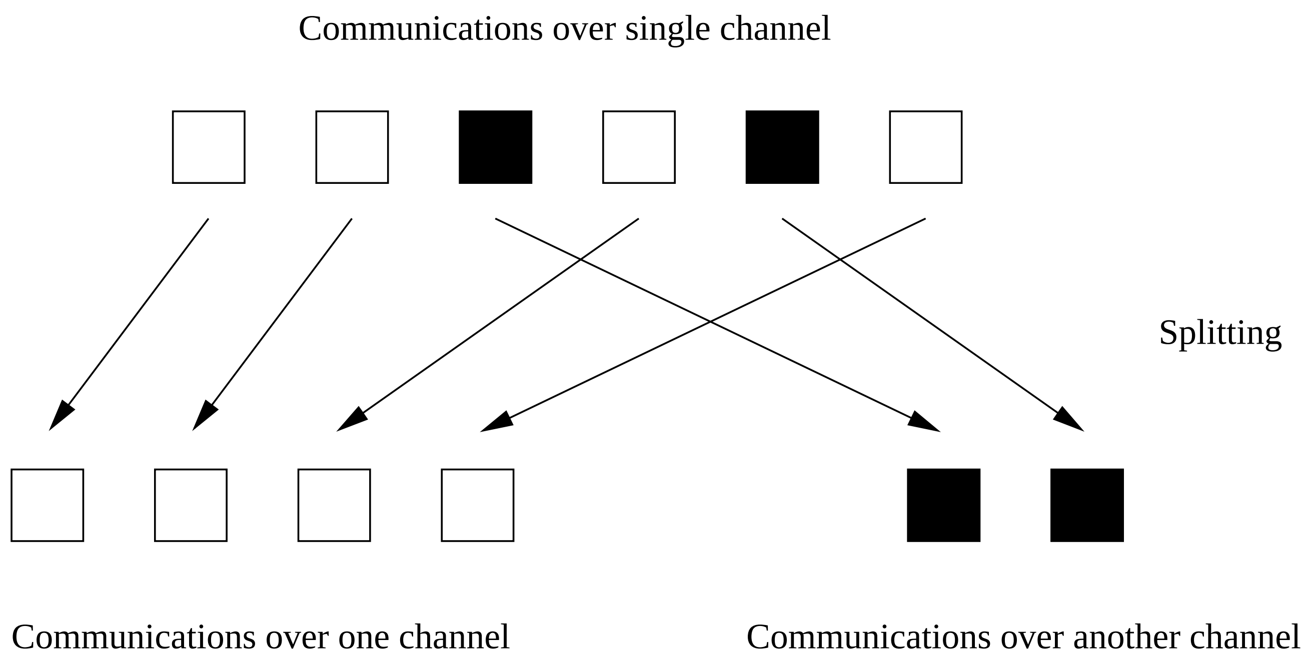
**Directed path in example graph**



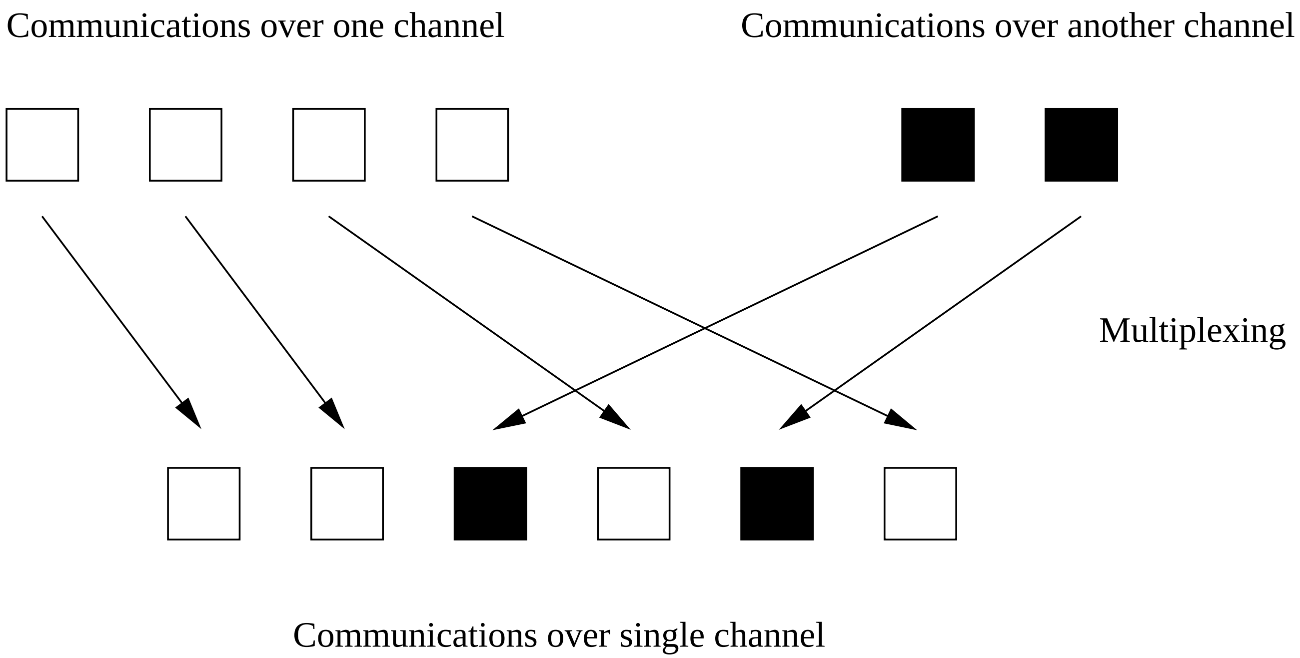

**Three examples of trees with seven vertices**



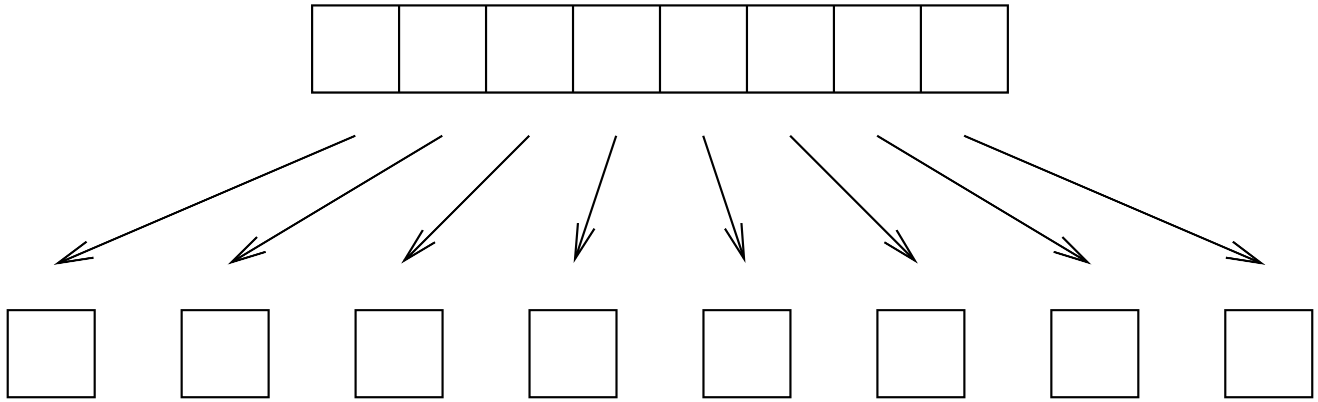
**Directed spanning tree of example graph**



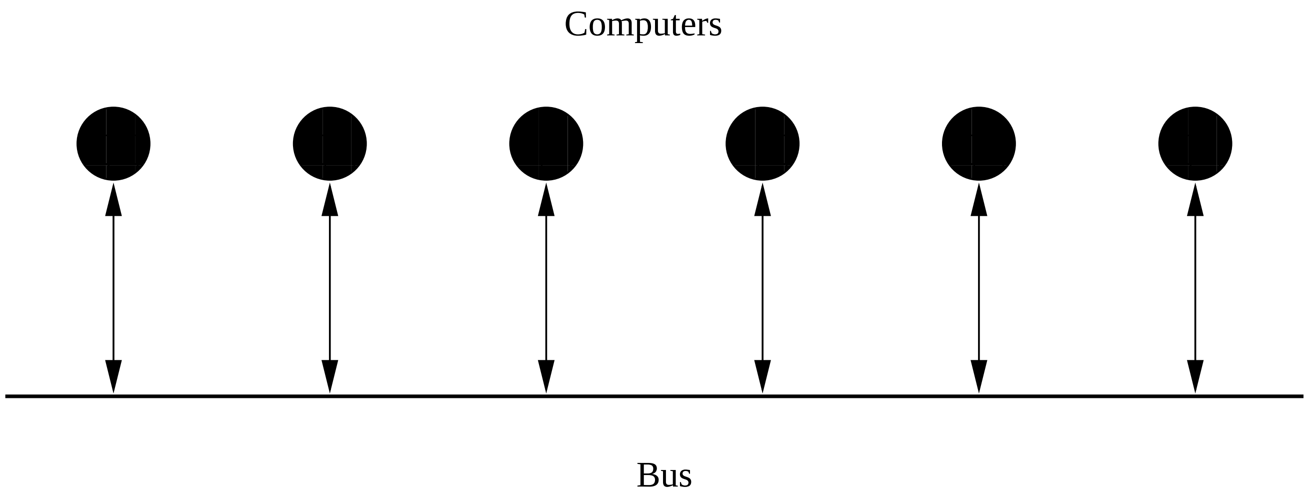

**Splitting a channel over several channels**



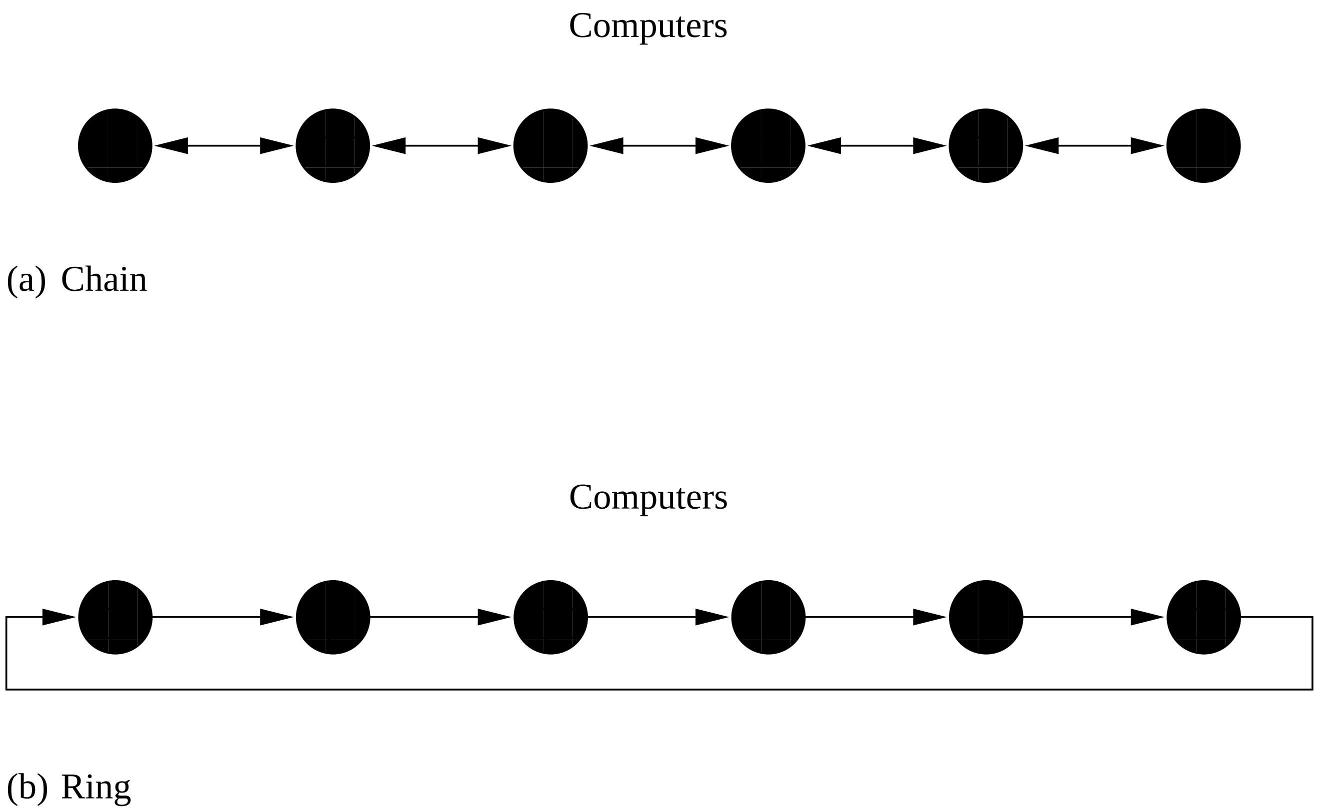

**Multiplexing several channels on to a single channel**



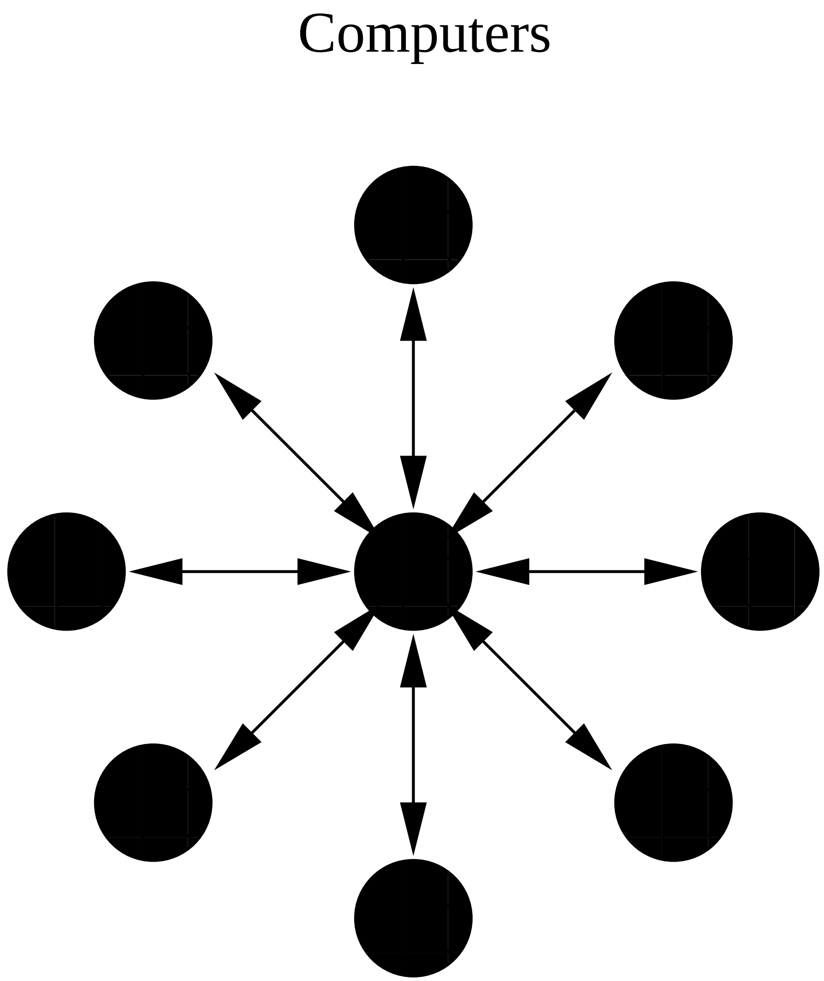
**Splitting a character communication channel**



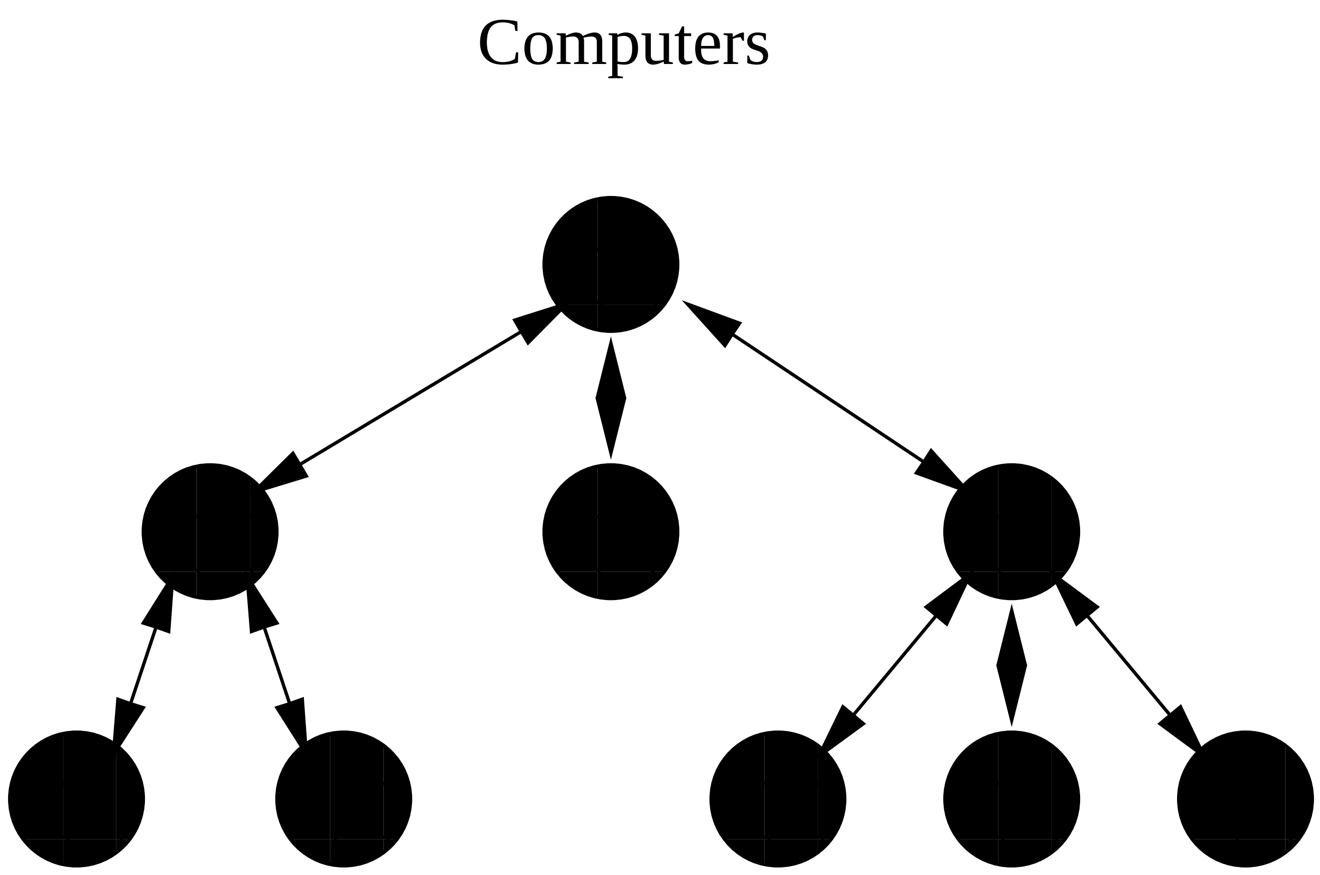

**Multipeer channel using common medium**



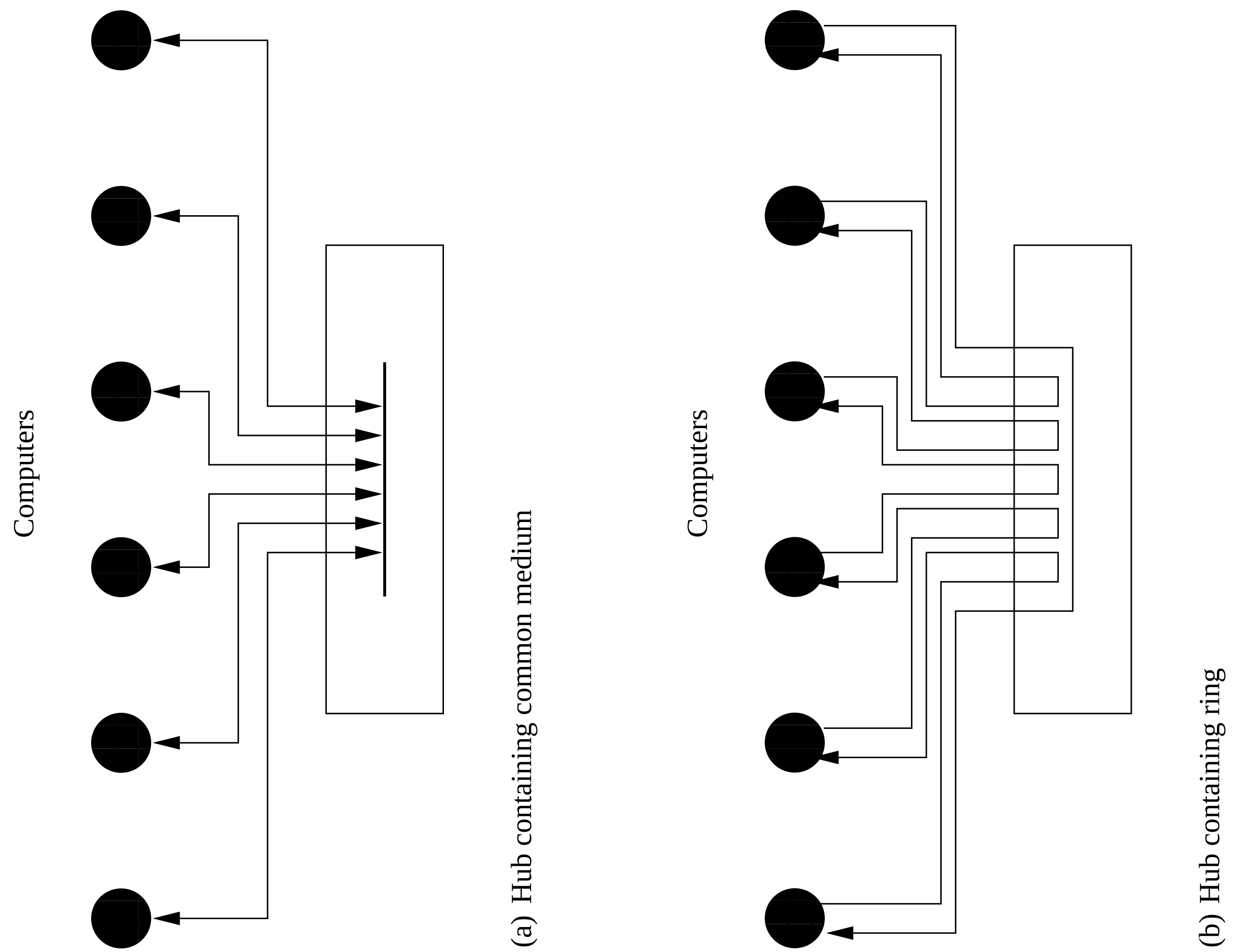

**Multipeer channels using chain and ring arrangements**



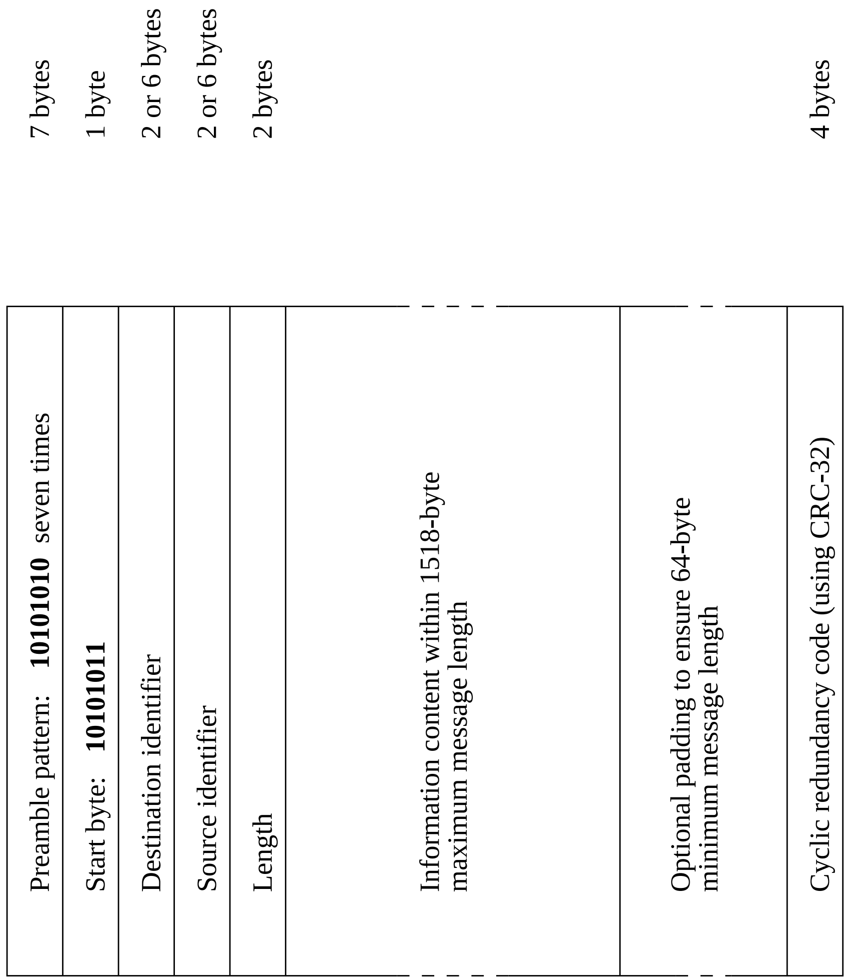

**Multipeer channel using star arrangement**



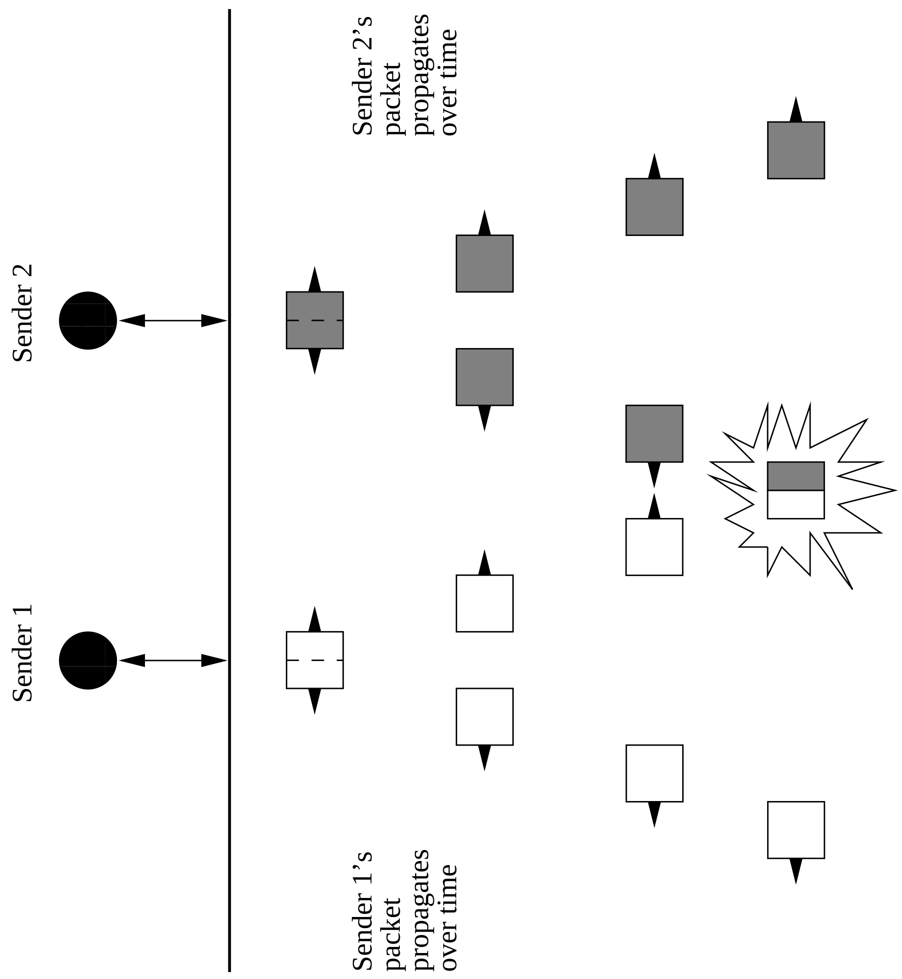

**Multipeer channel using tree arrangement**




**Hub arrangements for common medium and ring networks**

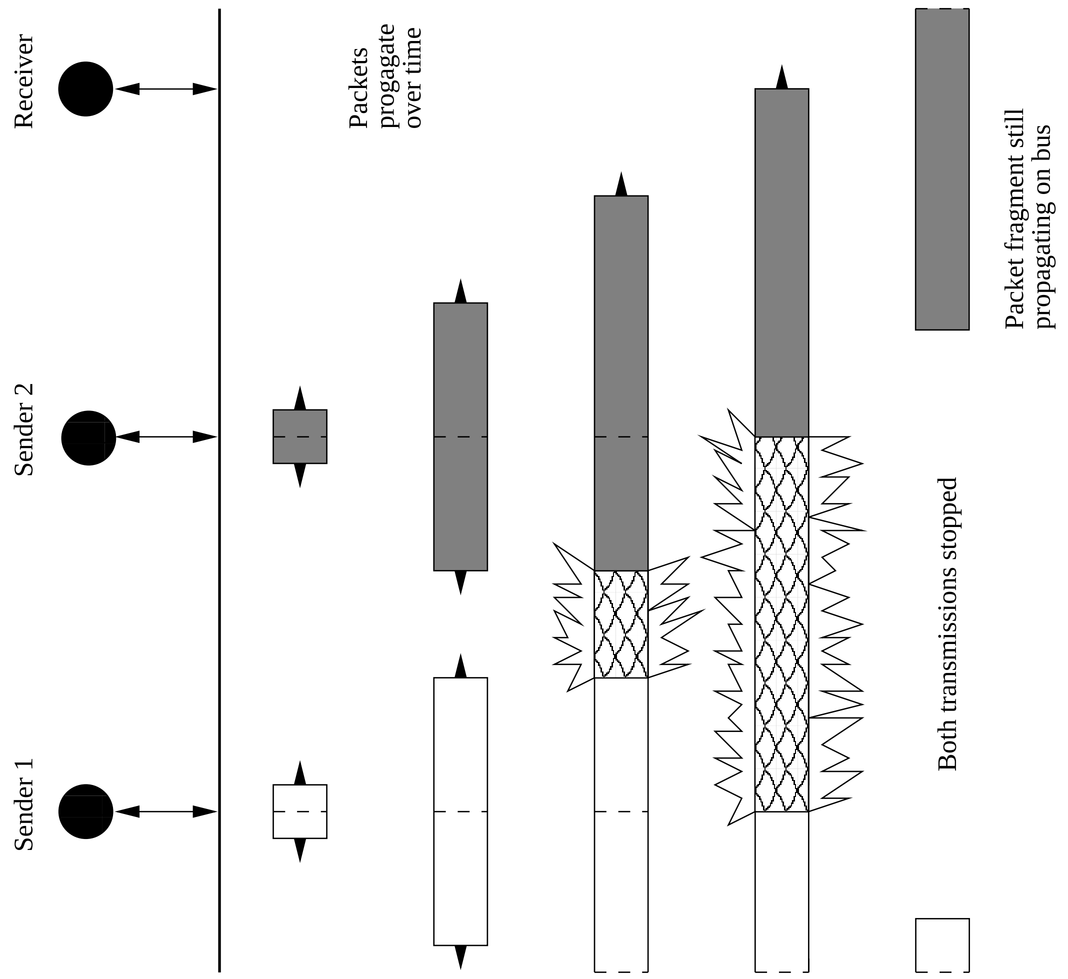



**Format of IEEE 802.3 ethernet message**




**Ethernet collision invisible to transmitters**

# Ethernet collision invisible to a receiver

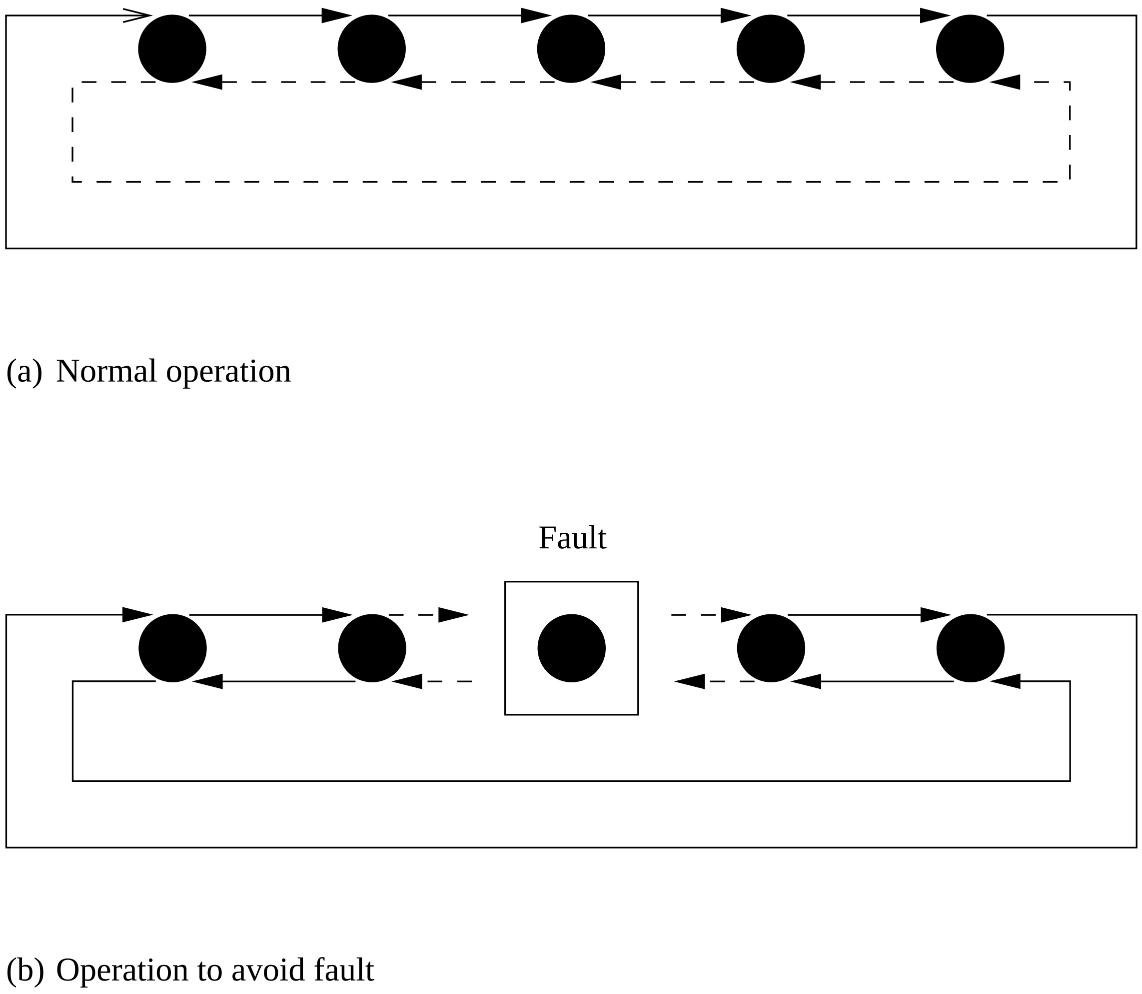


| Field | Size |
|---|---|
| Start byte: non-binary pattern | 1 byte |
| Access control byte | 1 byte |
| Frame control byte | 1 byte |
| Destination identifier | 2 or 6 bytes |
| Source identifier | 2 or 6 bytes |
| Information content | |
| Cyclic redundancy code ( using CRC-32) | 4 bytes |
| Stop byte: non-binary pattern | 1 byte |
| Frame status byte | 1 byte |

# Format of IEEE 802.5 token ring message

## Format of FDDI message

| | |
|---|---|
| Preamble: non-binary pattern eight times | 8 bytes |
| Start byte: non-binary pattern | 1 byte |
| Frame control byte | 1 byte |
| Destination identifier | 2 or 6 bytes |
| Source identifier | 2 or 6 bytes |
| Information content | |
| Cyclic redundancy code ( using CRC-32) | 4 bytes |
| Stop nibble or byte: non-binary pattern | 1 nibble or 1 byte |
| Frame status byte | 1 byte |




**Single FDDI ring formed from dual ring channels**

| | |
|---|---|
| Preamble: non-binary pattern five times | 5 nibbles |
| Cycle header | 24 nibbles |
| Group 0 | 129 bytes |
| Group 1 | 129 bytes |
| | 8 * 129 bytes |
| Group 10 | 129 bytes |
| Group 11 | 129 bytes |

(a) Overall cycle format

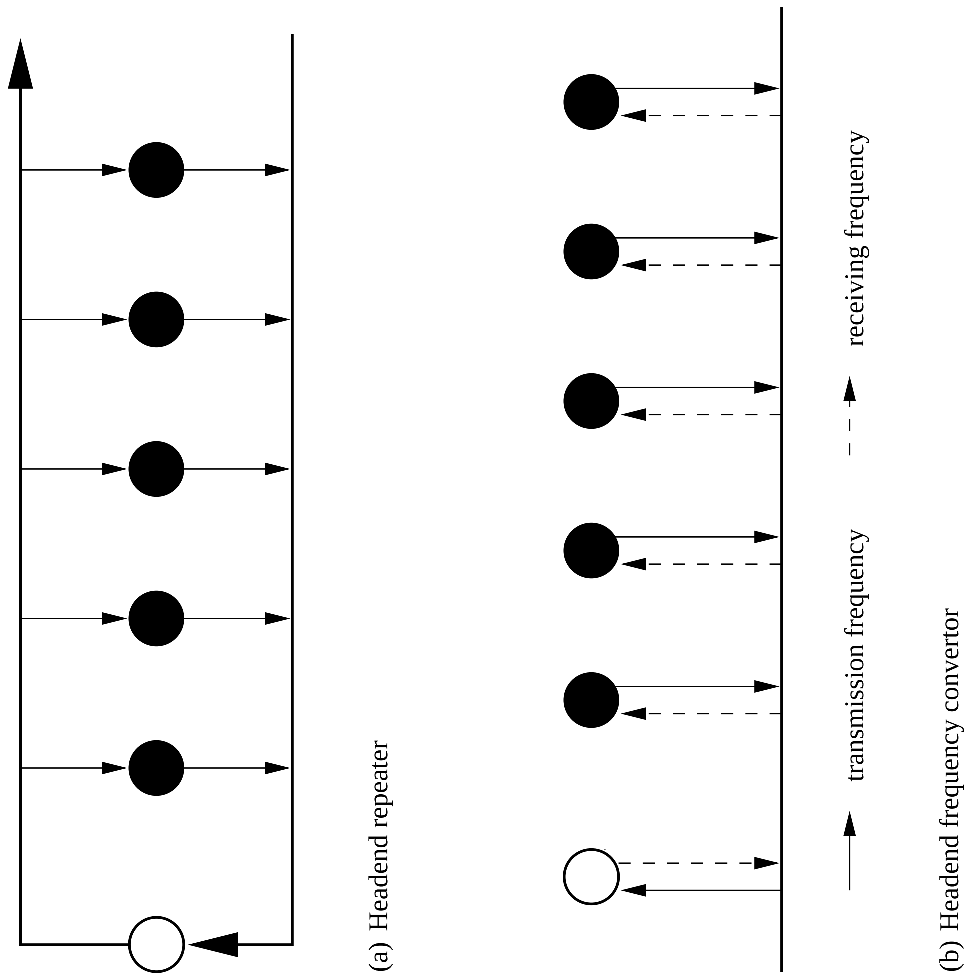
| | |
|---|---|
| Dedicated packet byte | 1 byte |
| Wideband channel 0 | 8 bytes |
| Wideband channel 1 | 8 bytes |
| | 12 * 8 bytes |
| Wideband channel 14 | 8 bytes |
| Wideband channel 15 | 8 bytes |

(b) Group format within cycle

## Format of FDDI-II cycle

| | |
|---|---|
| Preamble: **10101010** one or more times | 1 or more bytes |
| Start byte: non-binary pattern | 1 byte |
| Frame control byte | 1 byte |
| Destination identifier | 2 or 6 bytes |
| Source identifier | 2 or 6 bytes |
| Information content | |
| Cyclic redundancy code ( using CRC-32) | 4 bytes |
| Stop byte: non-binary pattern | 1 byte |

# Format of IEEE 802.4 token bus message



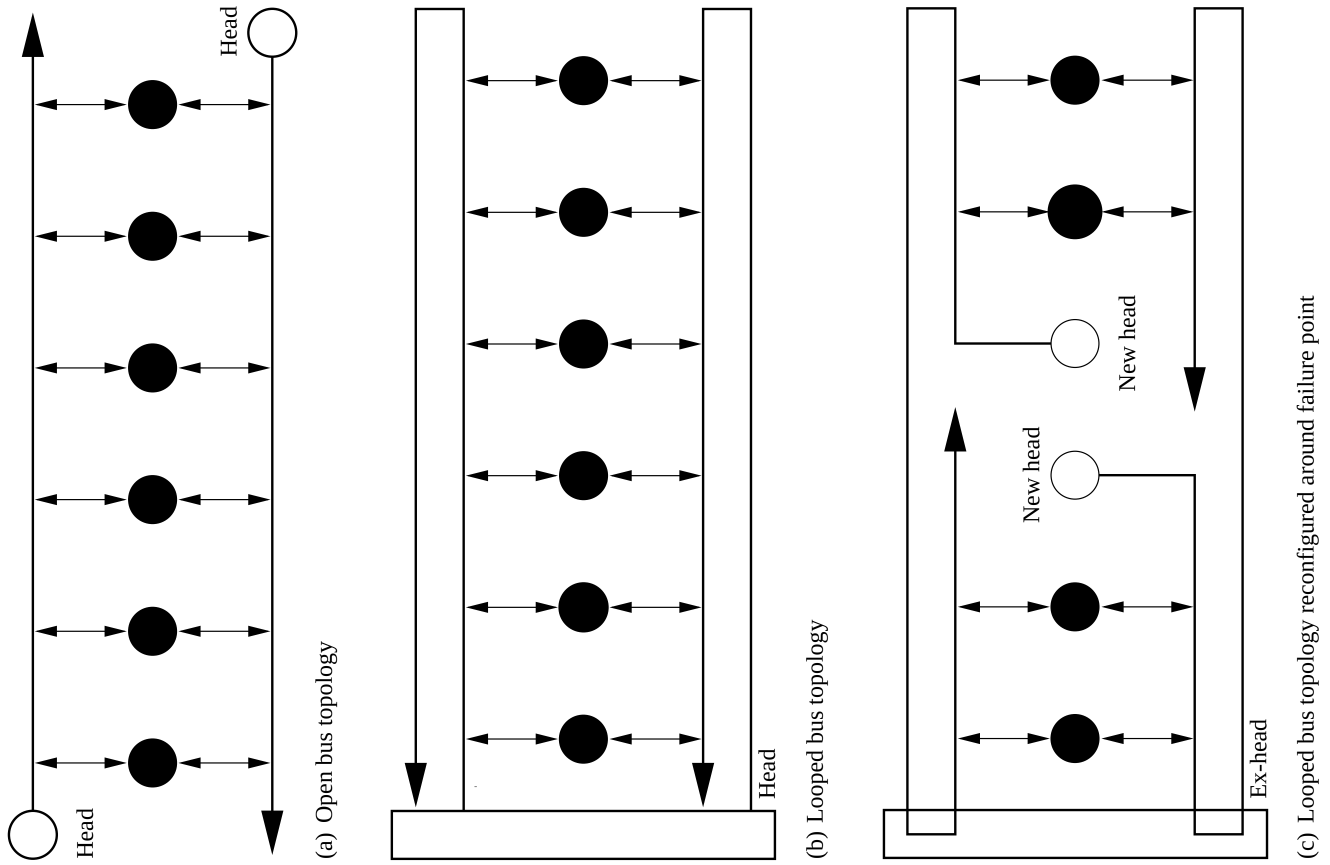

**Two implementations of IEEE 802.4 bus**

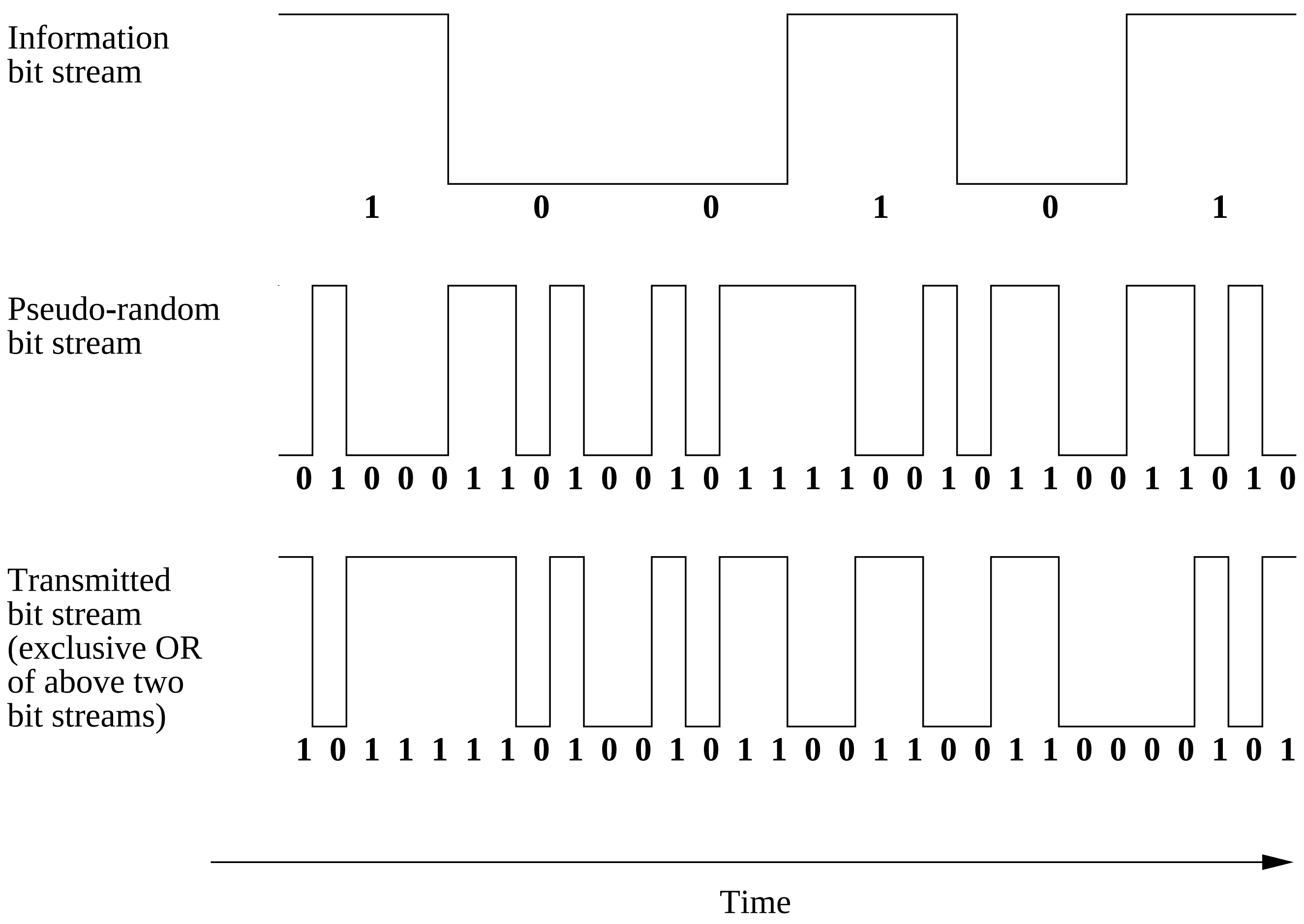
Segment header

| | |
|---|---|
| Access control byte | 1 byte |
| Virtual channel identifier | 20 bits |
| Payload type field | 2 bits |
| Segment priority field | 2 bits |
| Segment header CRC (uses CRC-8) | 1 byte |
| Segment payload | 48 bytes |

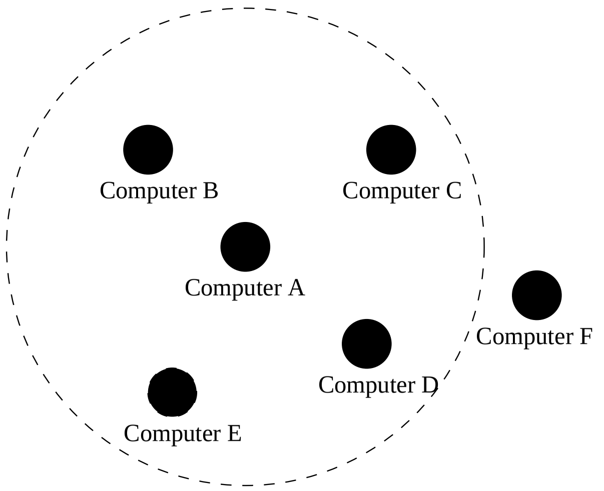
**Format of DQDB message**

# Two implementations of DQDB bus

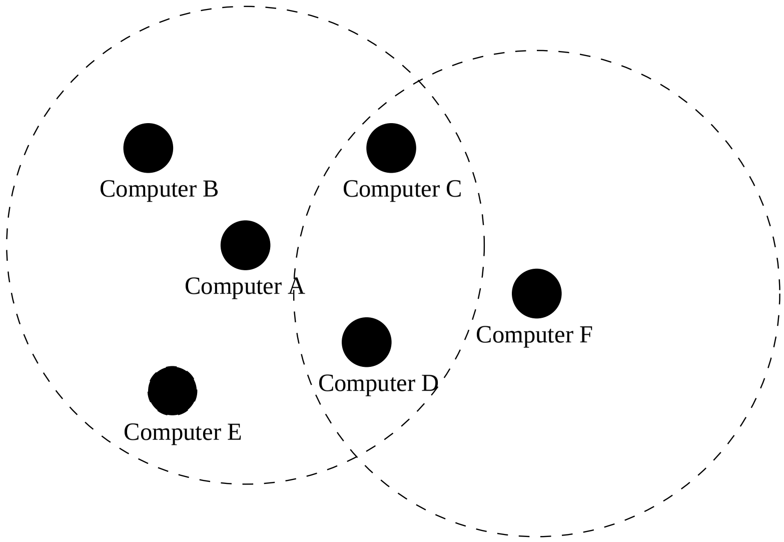





**Example of direct sequence spread spectrum transmission**

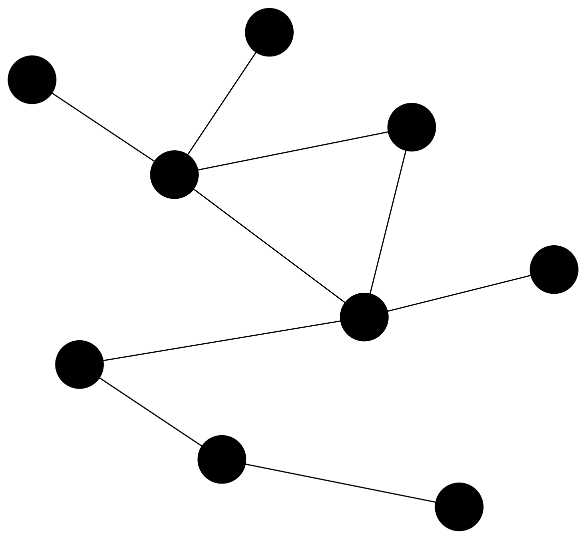



(a) Computer A is heard by Computers B, C, D and E, but not F

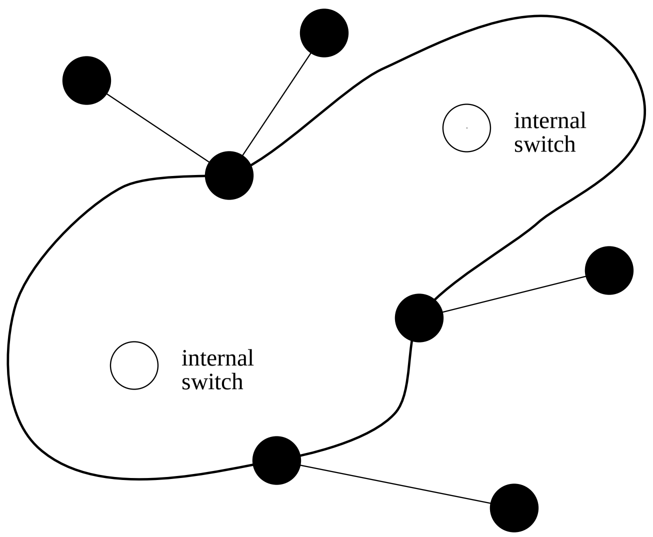



(b) Computer F collides with A at Computers C and D

# Hidden station problem in wireless network

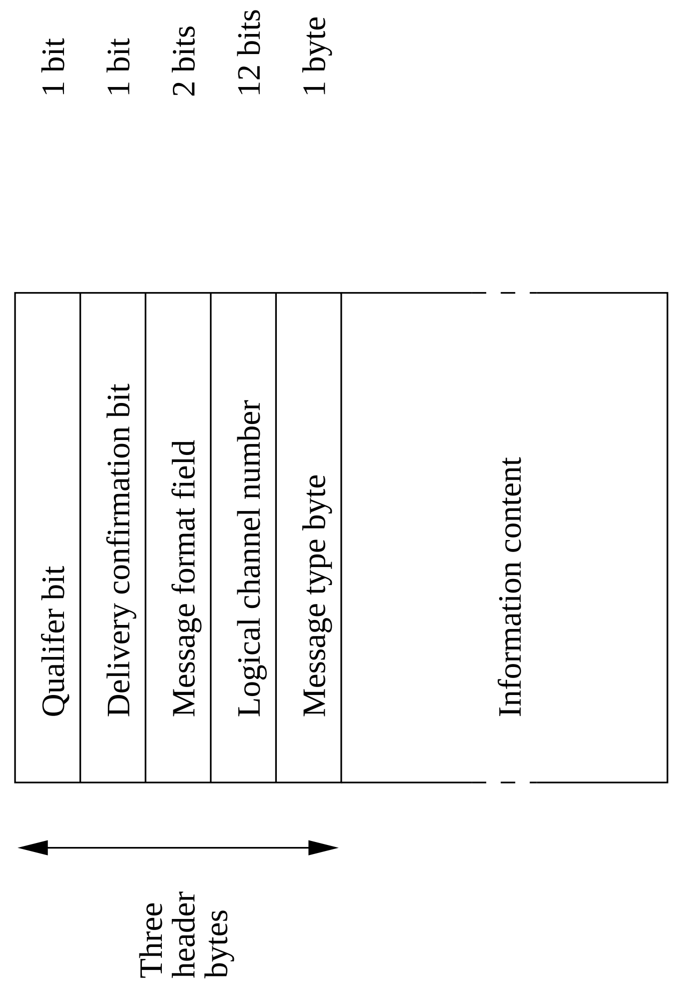


(a) Graph view of network with some computers doing switching




(b) Black box view of network shown in (a)

**Two ways of viewing a network**




**Format of X.25 message**

| Field | Size |
|---|---|
| Header byte 1 | 1 byte |
| Header byte 2 | 1 byte |
| Information content | |
| Cyclic redundancy code (using CRC-CCITT) | 2 bytes |

**Format of frame relay message**

| Bit 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Logical channel identifier | | | | | | Comm/ resp | **0** |
| Logical channel identifier | | | | FECN | BECN | DE | **1** |

(a) Two-byte header - Bit 0 is the extended address bit

| Bit 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| Logical channel identifier | | | | | | Comm/ resp | **0** |
| Logical channel identifier | | | | FECN | BECN | DE | **0** |
| Logical channel identifier | | | | | | | **0** |
| Logical channel identifier | | | | | | | **1** |

(b) Four-byte header - Bit 0 is the extended address bit

## Examples of frame relay header format

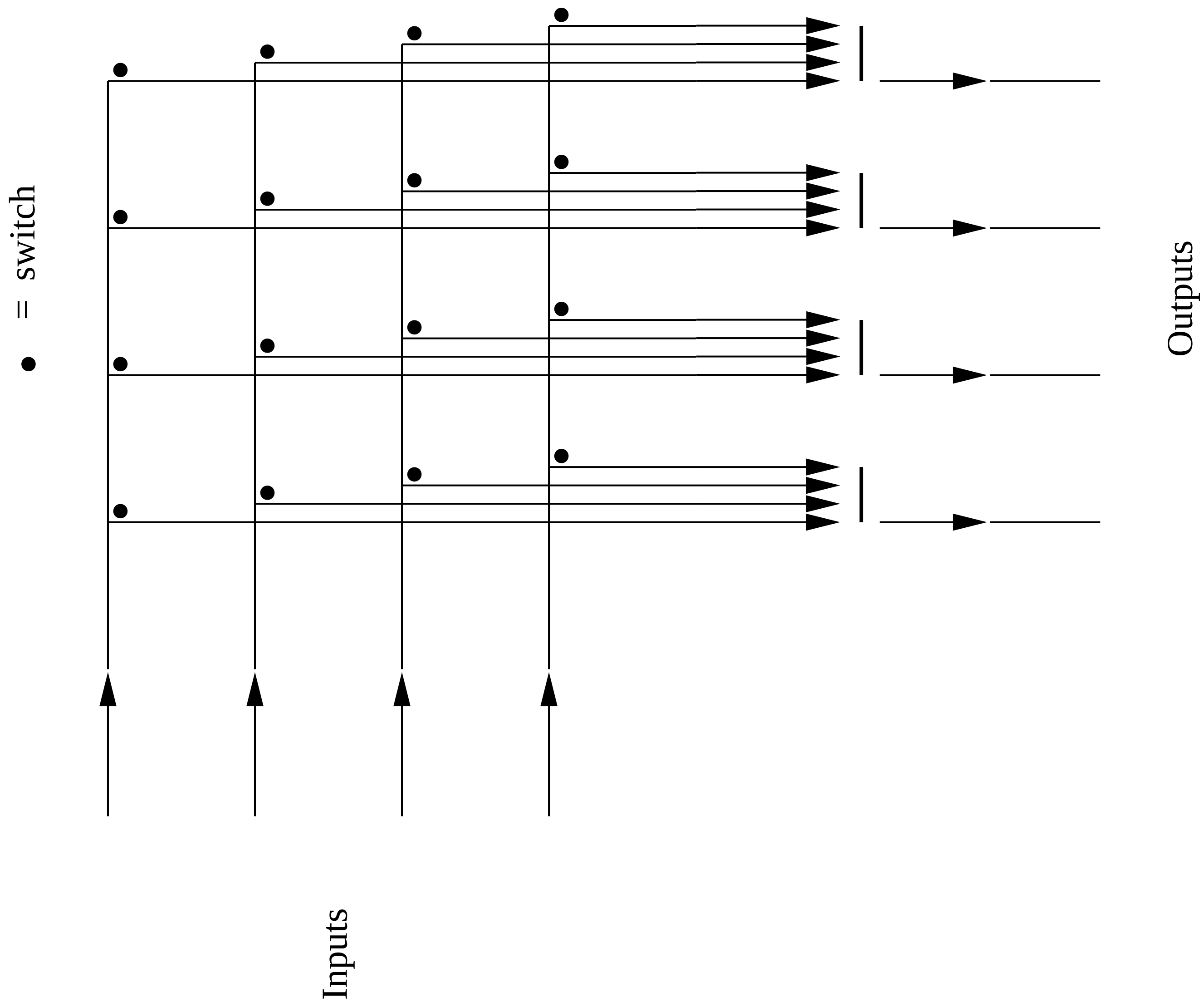
| | |
|---|---|
| Virtual path identifier (VPI) | 12 bits |
| Virtual channel identifier (VCI) | 16 bits |
| Payload type | 3 bits |
| Cell loss priority | 1 bit |
| Cyclic redundancy code (using CRC-8 generator) | 1 byte |
| Information content | 48 bytes |

(a) Format of ATM message used between switches

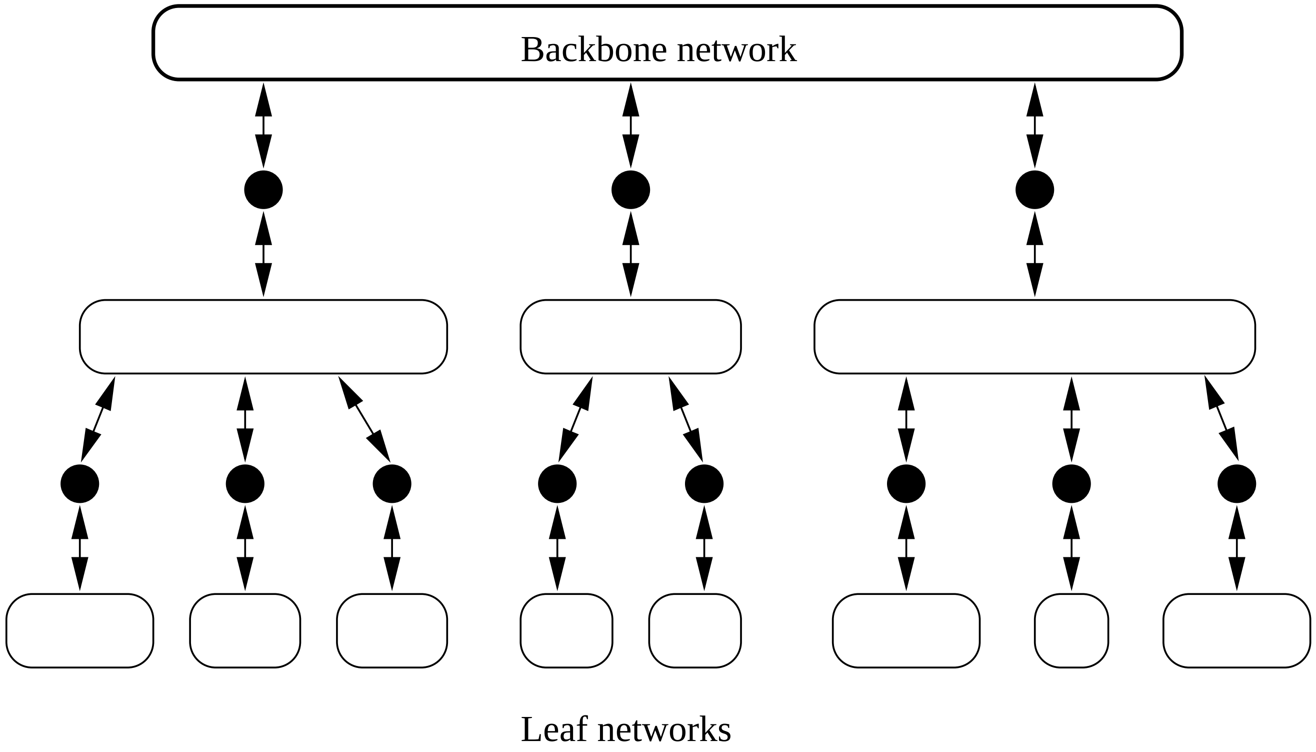
| | |
|---|---|
| Generic flow control | 4 bits |
| Virtual path identifier (VPI) | 8 bits |
| Virtual channel identifier (VCI) | 16 bits |
| Payload type | 3 bits |
| Cell loss priority | 1 bit |
| Cyclic redundancy code (using CRC-8 generator) | 1 byte |
| Information content | 48 bytes |

(b) Format of ATM message used between computers and switches

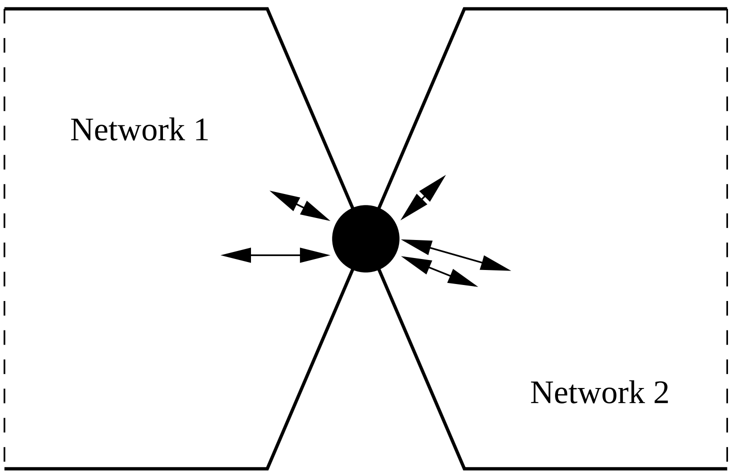
# Formats of ATM messages



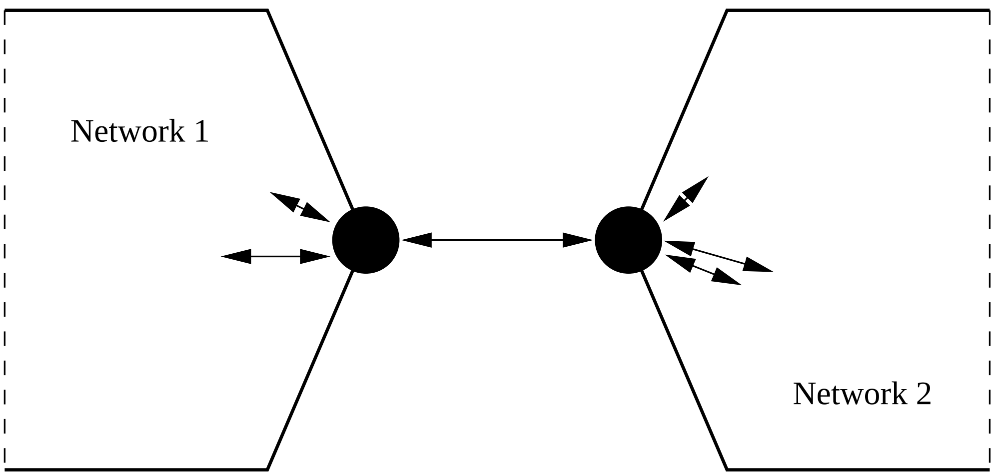

**Example of crossbar switch**




**Example of tree-structured inter-network**




(a) Single switch

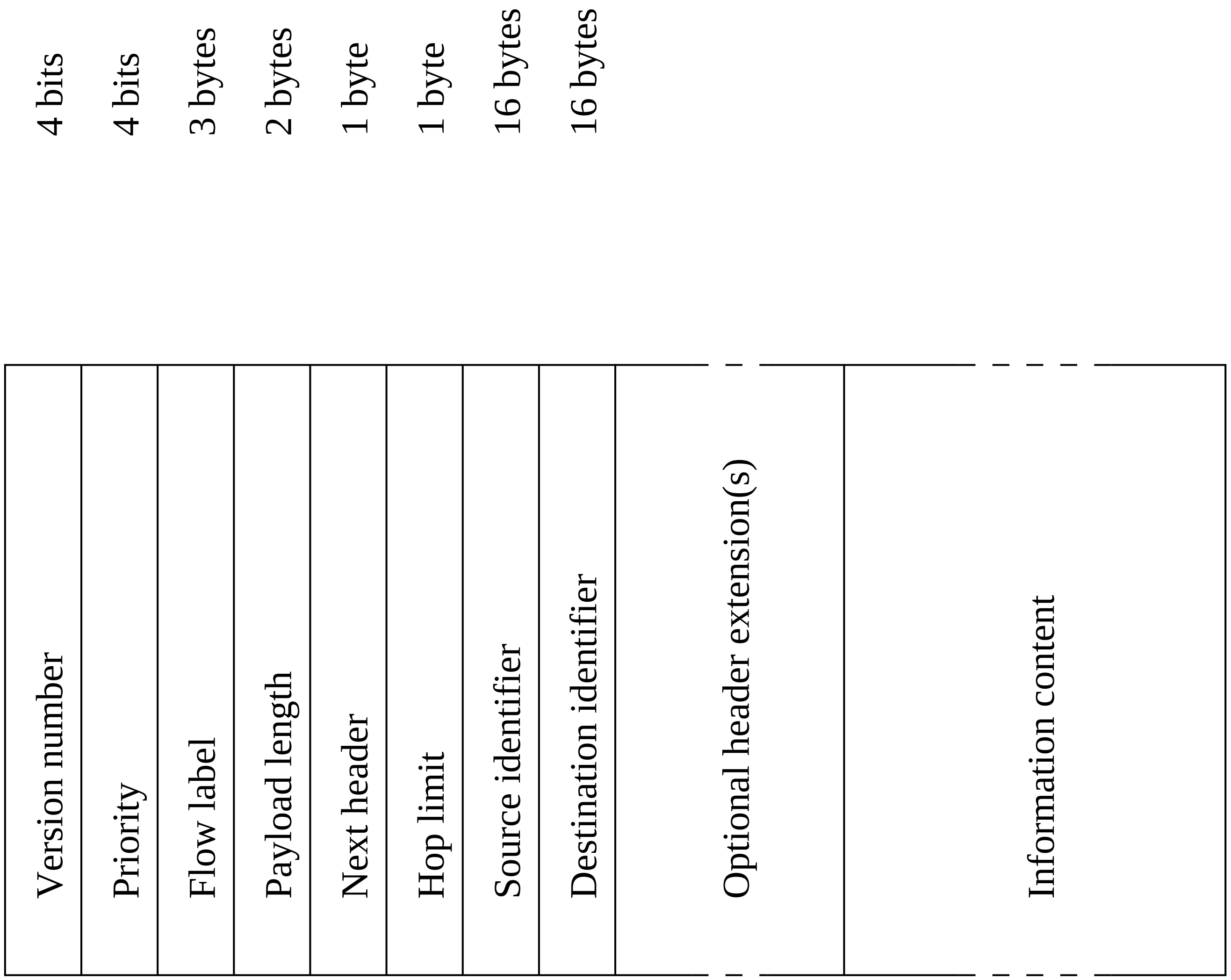



(b) Two half-switches connected by channel

## A switch implemented as two half-switches

## Format of IP version 4 message

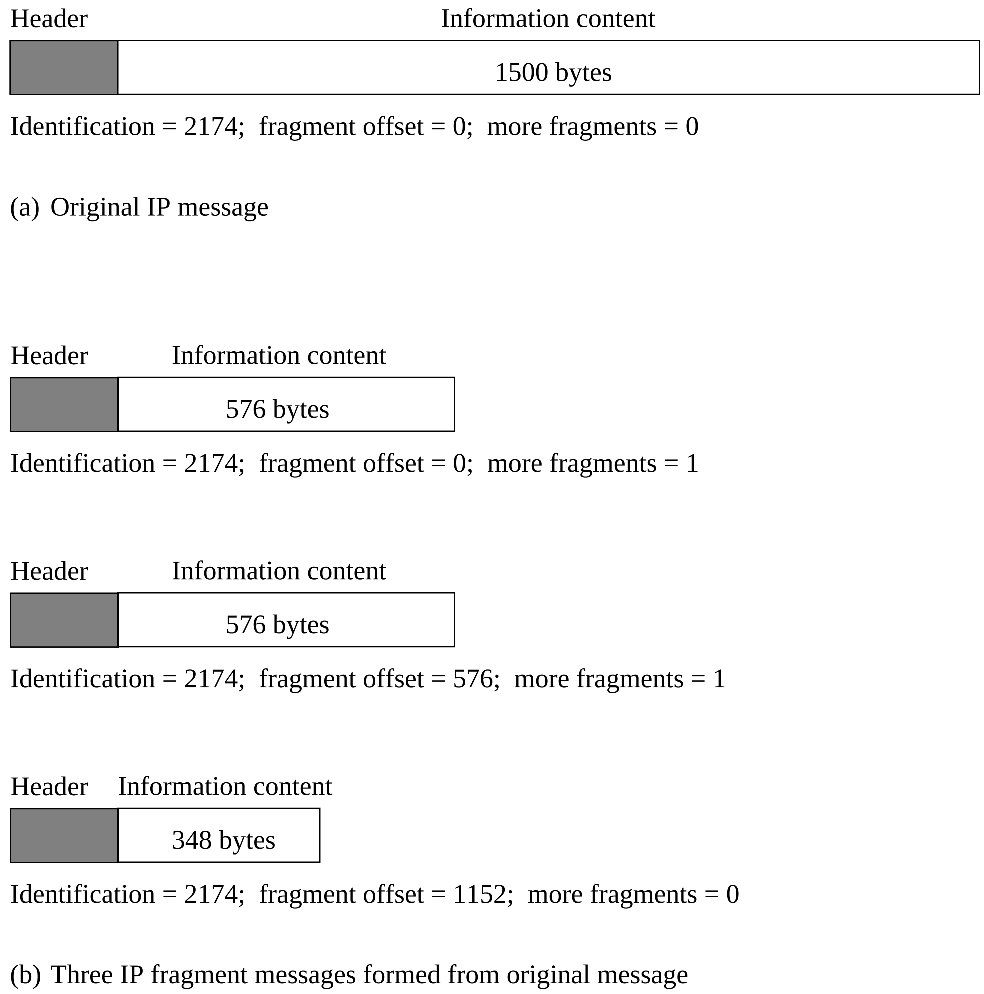
| | |
|---|---|
| Version number | 4 bits |
| Header length | 3 bits |
| Service type | 1 byte |
| Total length | 2 bytes |
| Identification number | 2 bytes |
| Flags | 3 bits |
| Fragment offset | 13 bits |
| Time to live | 1 byte |
| Protocol | 1 byte |
| Header checksum | 2 bytes |
| Source identifier | 4 bytes |
| Destination identifier | 4 bytes |
| Optional header extension(s) | |
| Information content | |



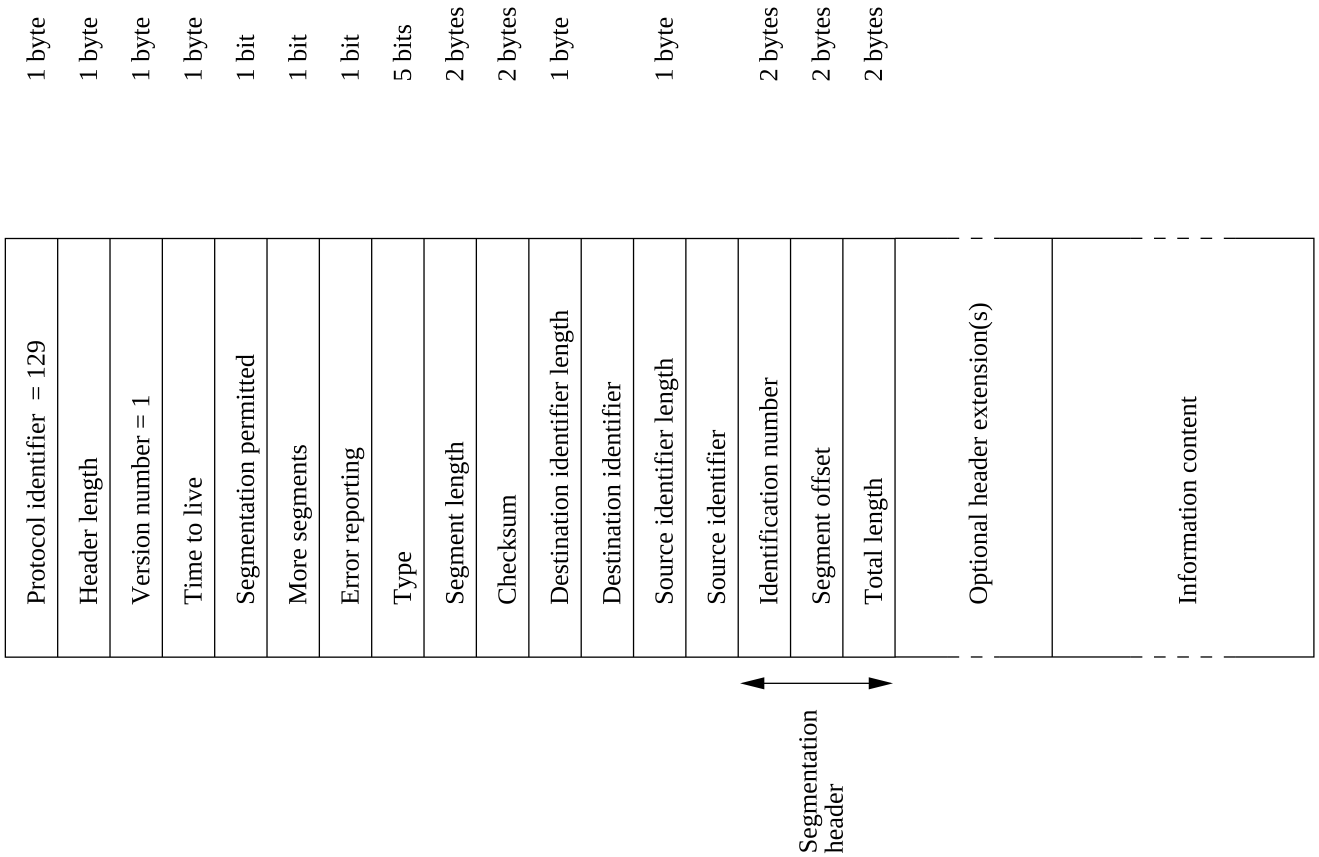

**Format of IP version 6 message**

| | |
|---|---|
| Type | 1 byte |
| Code value | 1 byte |
| Checksum | 2 bytes |
| Information content | |

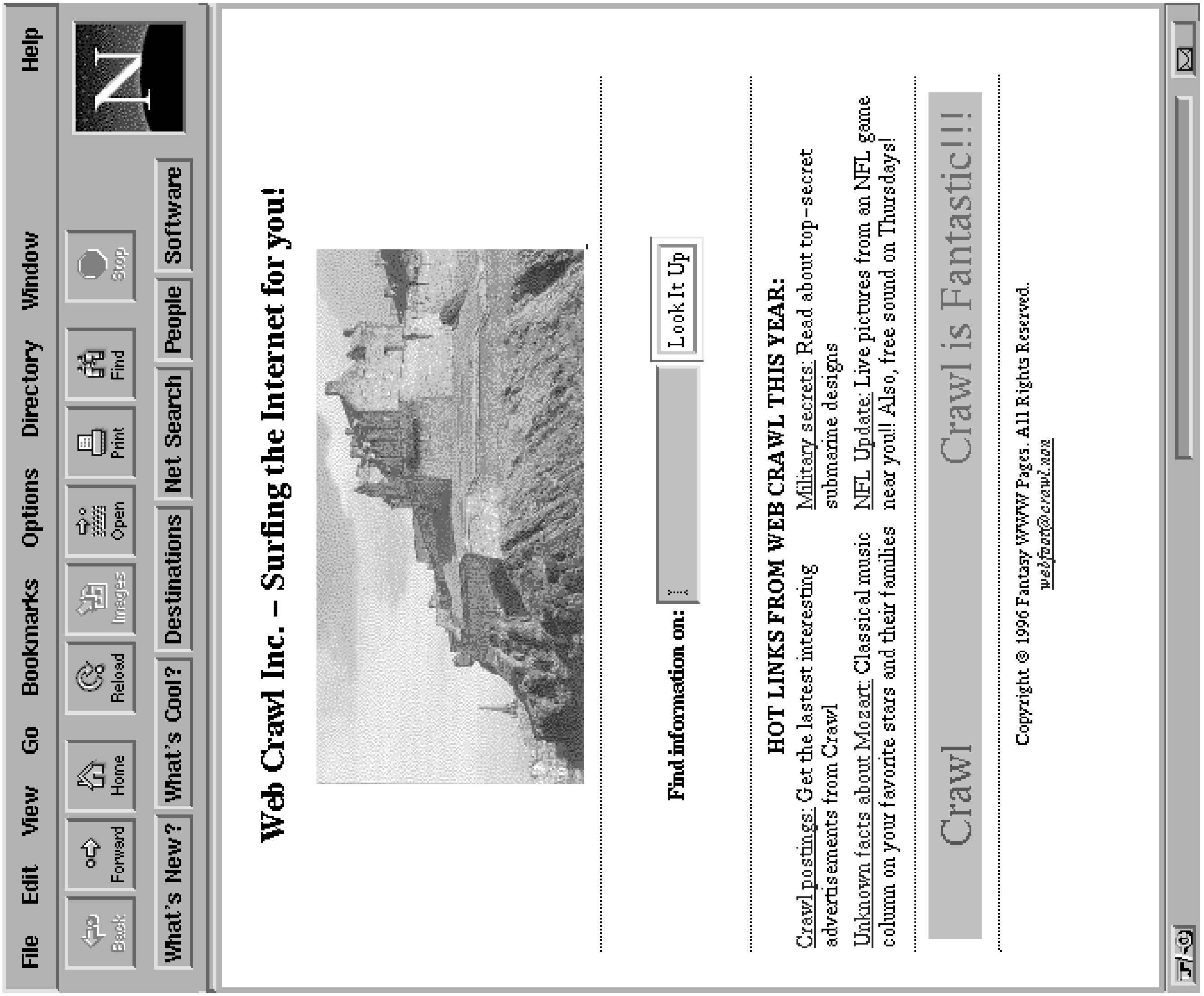
**General format of ICMP message**



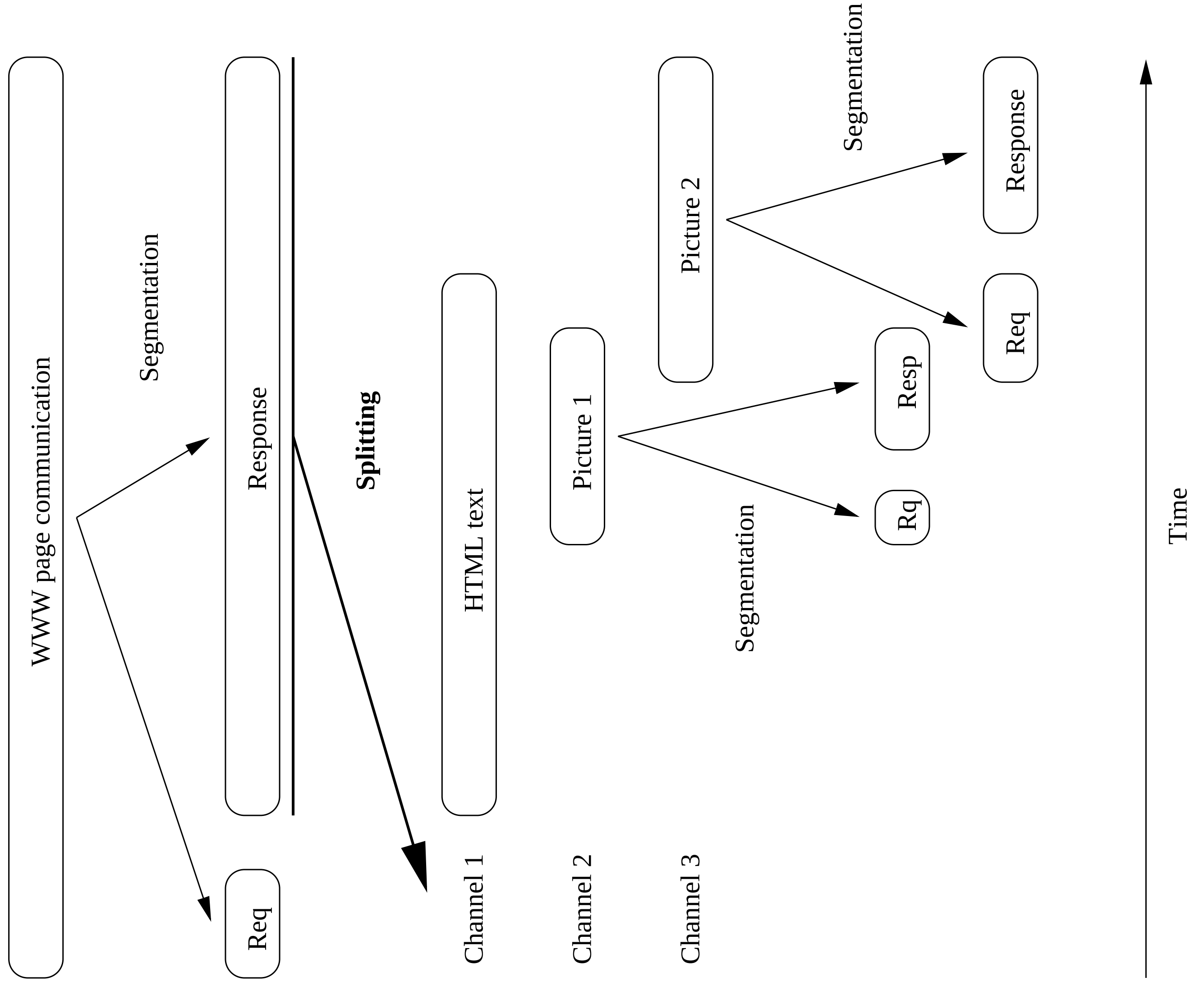

# Example of IP message fragmentation



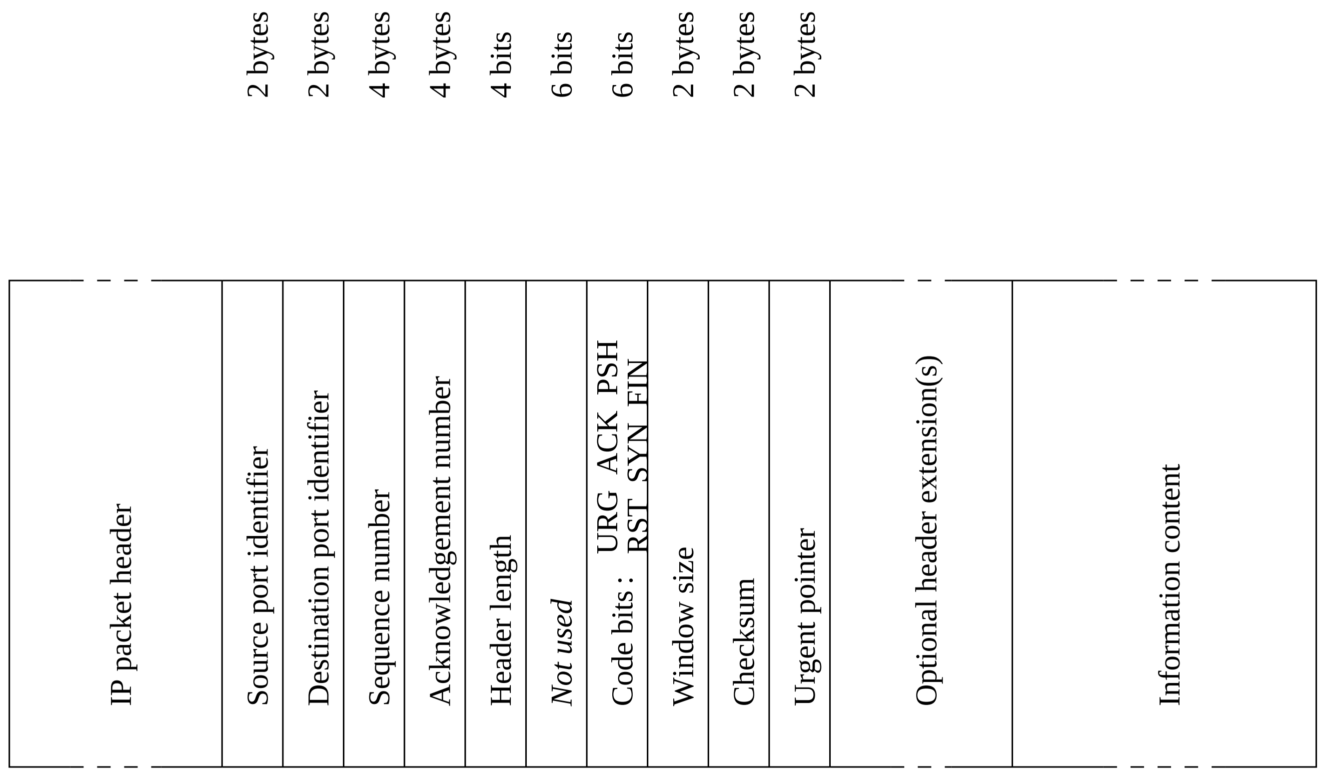

# Format of ISO CLNP message




Example WWW page displayed by Netscape Navigator



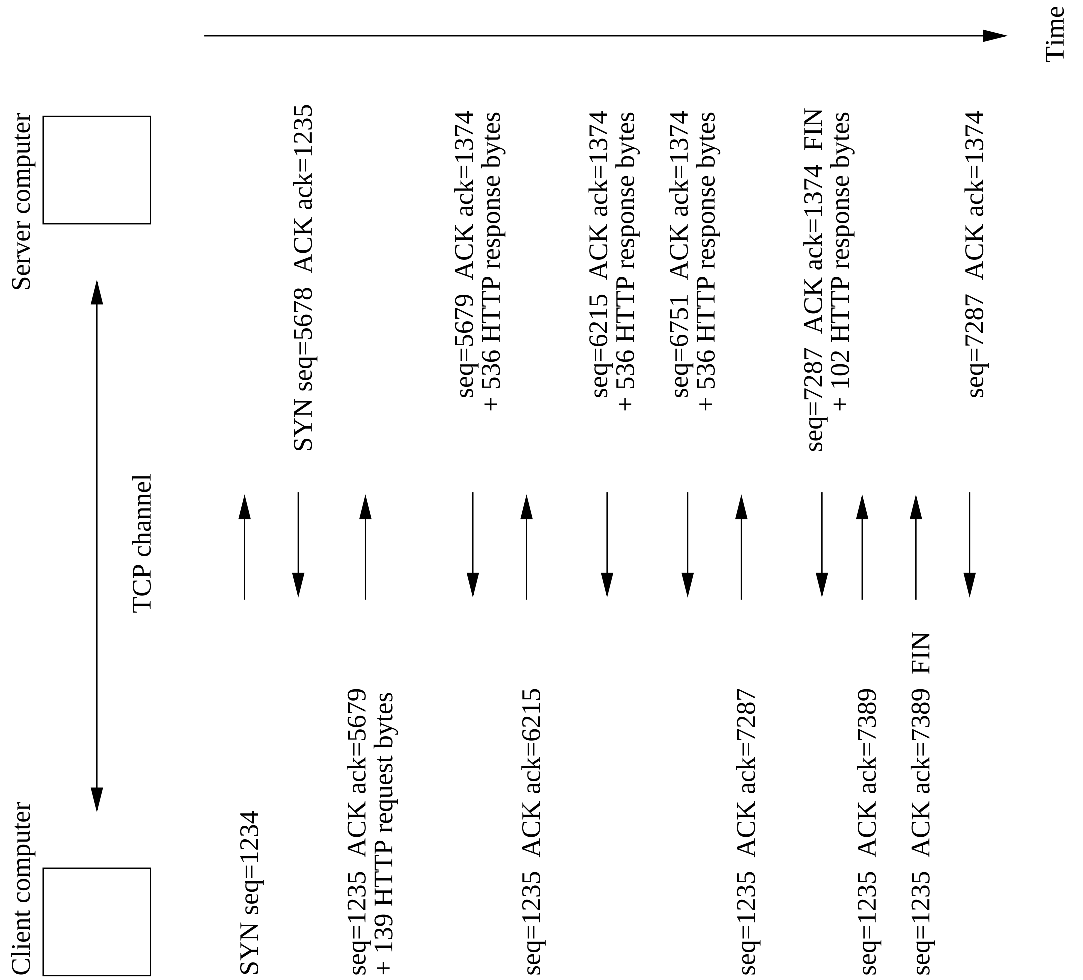

## Implementation of WWW page communication



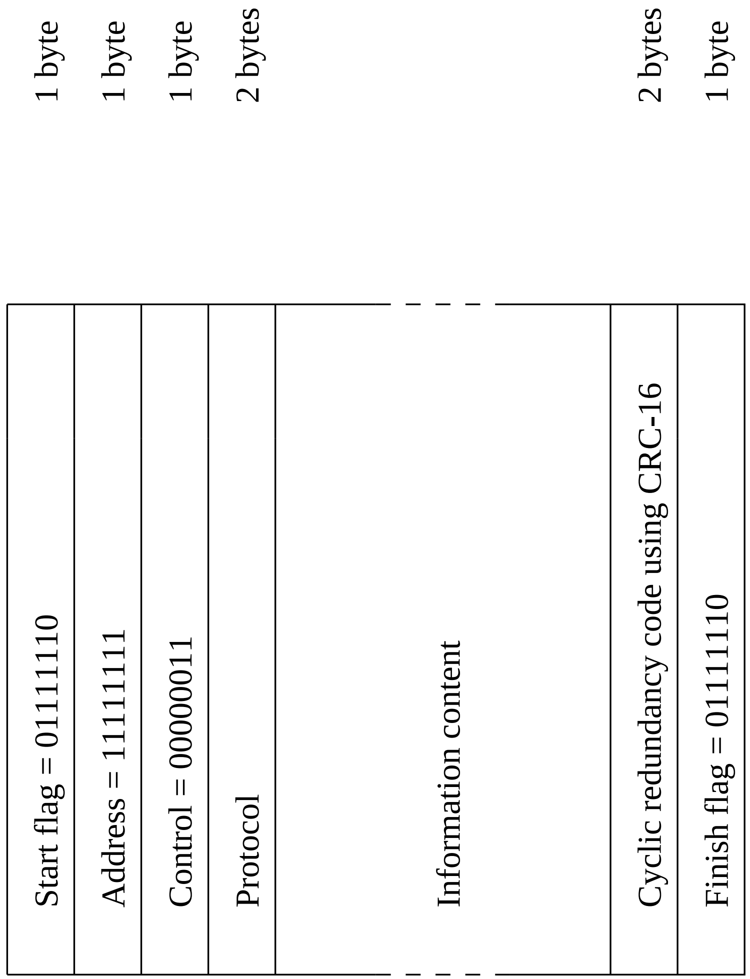

**TCP message format**

| | |
|---|---|
| Source IP identifier | 4 bytes |
| Destination IP identifier | 4 bytes |
| *Zero* | 1 byte |
| Protocol number = 6 (TCP) | 1 byte |
| TCP message length | 2 bytes |

**TCP pseudo-header format**




**TCP dialogue for example HTTP handshake**




**Format of PPP message**

| | |
|---|---|
| Protocol = **11000000 00100001** | 2 bytes |
| Code | 1 byte |
| Identifier | 1 byte |
| Length | 2 bytes |
| Option 1 type | 1 byte |
| Option 1 length | 1 byte |
| Option 1 information | |
| Option 2 type | 1 byte |
| Option 2 length | 1 byte |
| Option 2 information | |

**Example LCP request message with two options**

| Field | Size |
|---|---|
| *Reserved* | 1 byte |
| Sequence number | 1 byte |
| Message length | 2 bytes |
| Destination identifier | 8 bytes |
| Source identifier | 8 bytes |
| Other sub-fields | 4 bytes |
| Optional header extension | 0 to 20 bytes |
| Information content | |
| Padding | 0 to 3 bytes |
| Cyclic redundancy code | 0 or 4 bytes |
| *Reserved* | 1 byte |
| Sequence number | 1 byte |
| Message length | 2 bytes |

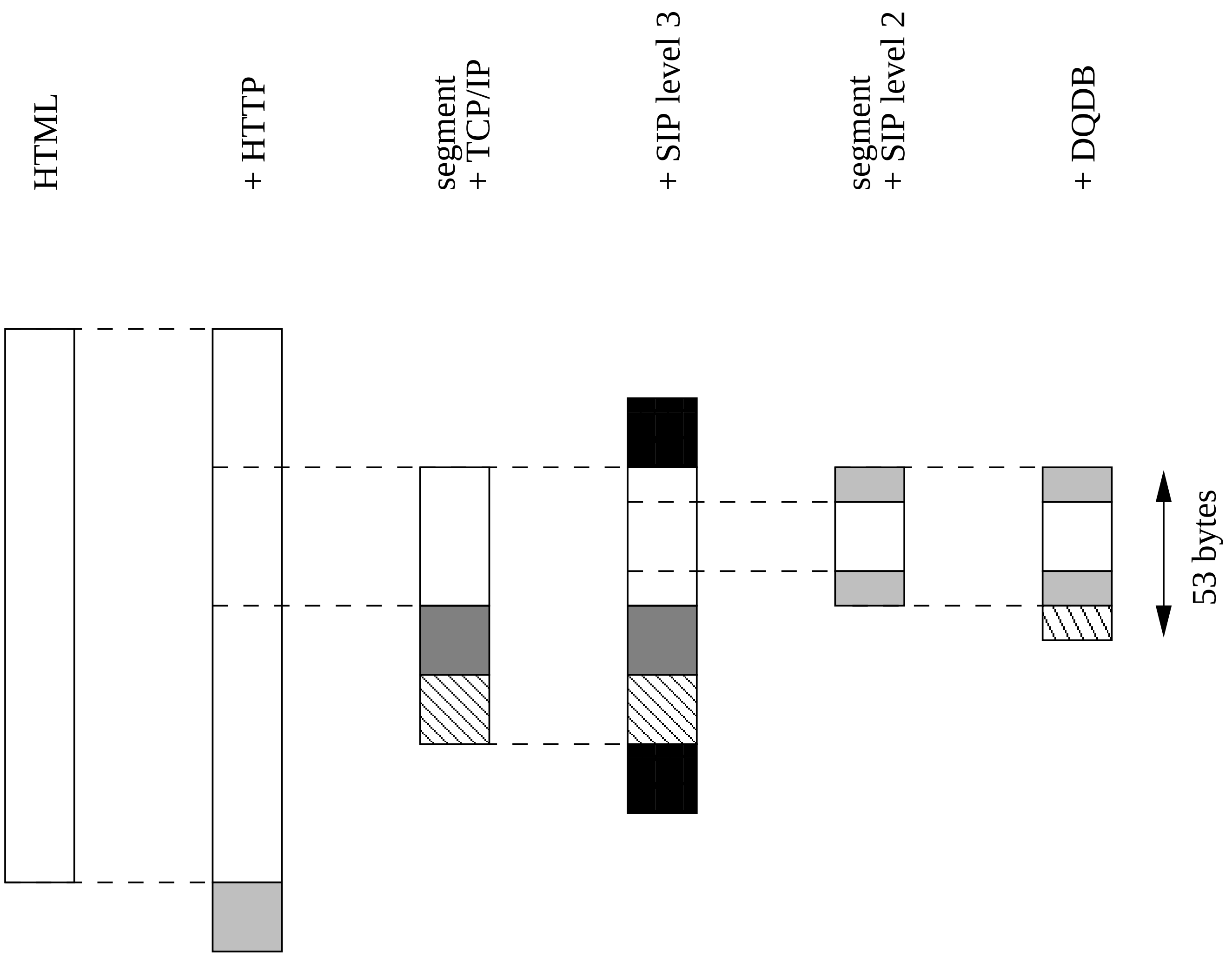
## Format of SIP level 3 message

| Field | Size |
|---|---|
| Message type | 2 bits |
| Sequence number | 4 bits |
| Message identifier | 10 bits |
| Information content | 44 bytes |
| Information length | 6 bits |
| Cyclic redundancy code | 10 bits |

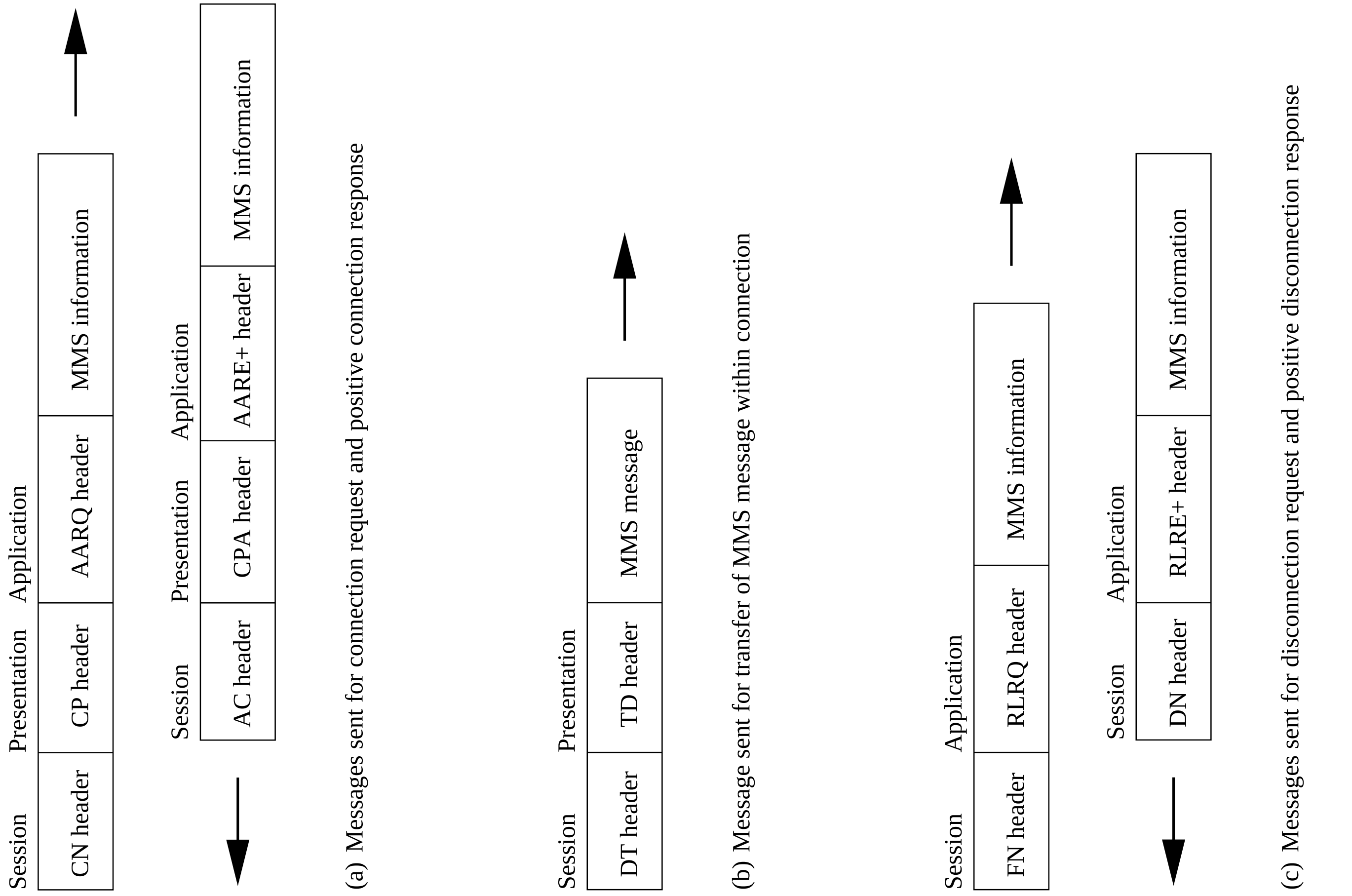
**Format of SIP level 2 message**

| | |
|---|---|
| LLC destination identifier = 170 | 1 byte |
| LLC source identifier = 170 | 1 byte |
| LLC control = **00000011** | 1 byte |
| SNAP identifier = 0 | 3 bytes |
| SNAP EtherType = 2048 | 2 bytes |
| Information content | |

**Format of LLC1 plus SNAP message**

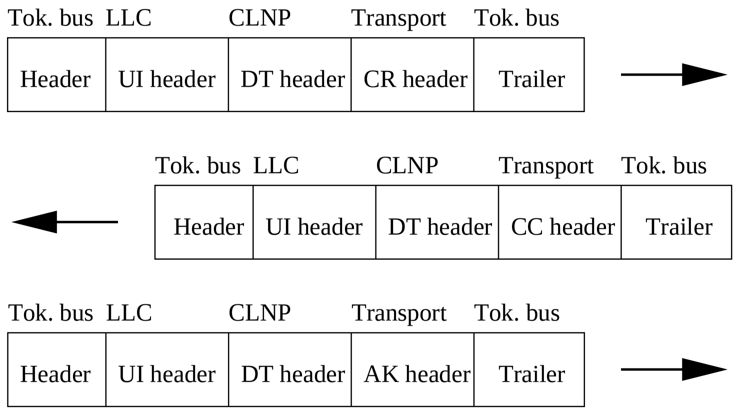



**Fragment of WWW page in a 53-byte message**

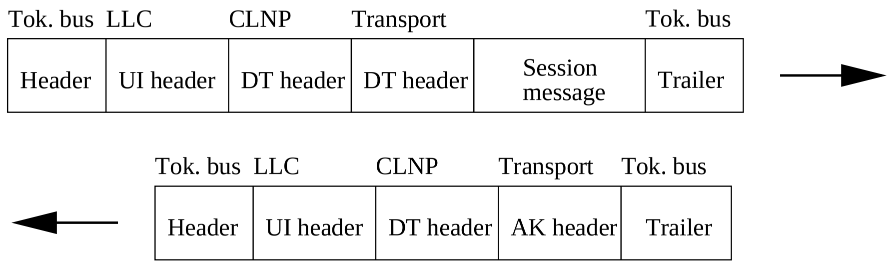



**Message exchanges for MMS connection management**

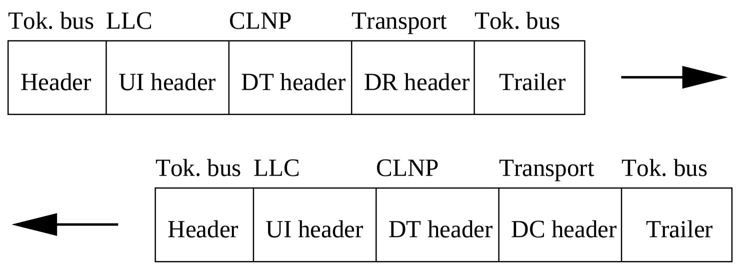
Gordon Brebner




(a) Messages sent for connection request and positive connection response

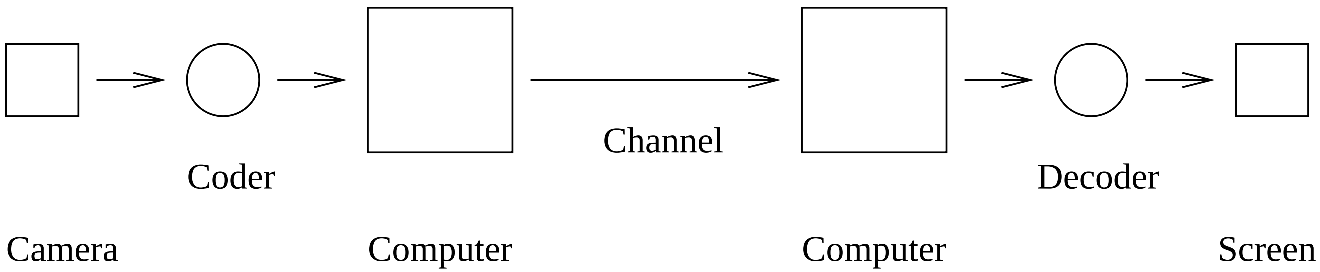



(b) Messages sent for transfer of session message within connection

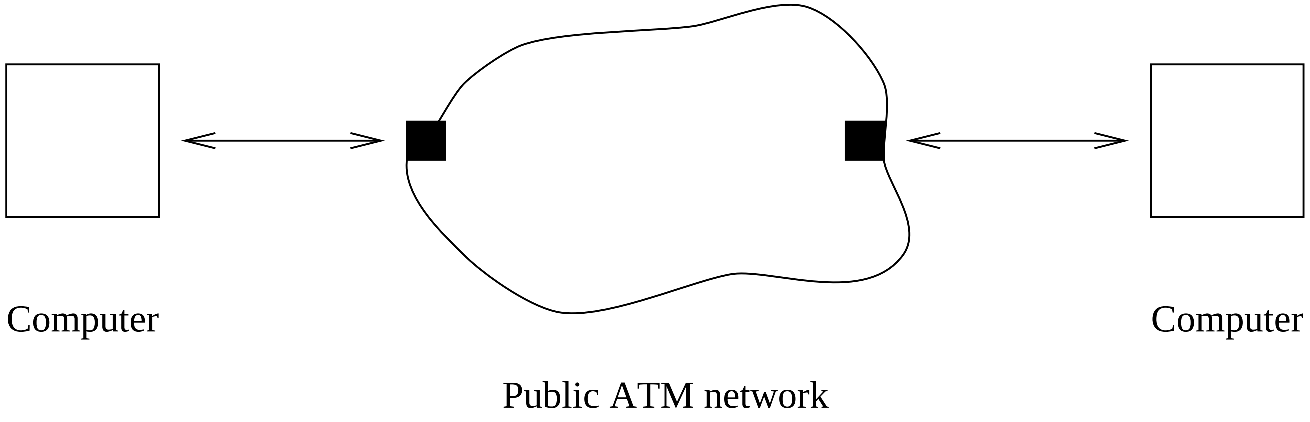



(c) Messages sent for disconnection request and positive disconnection response

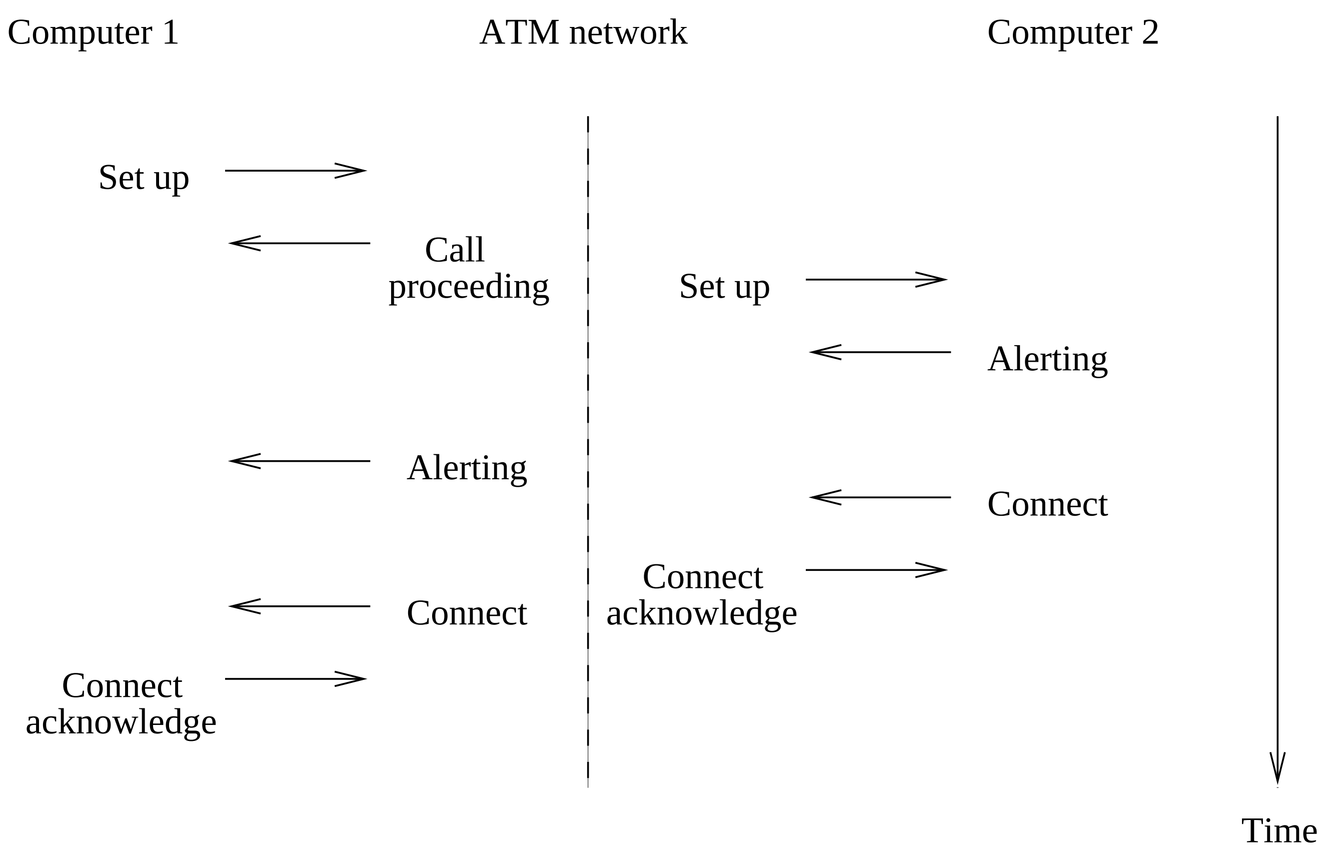
## Message exchanges for transport connection management



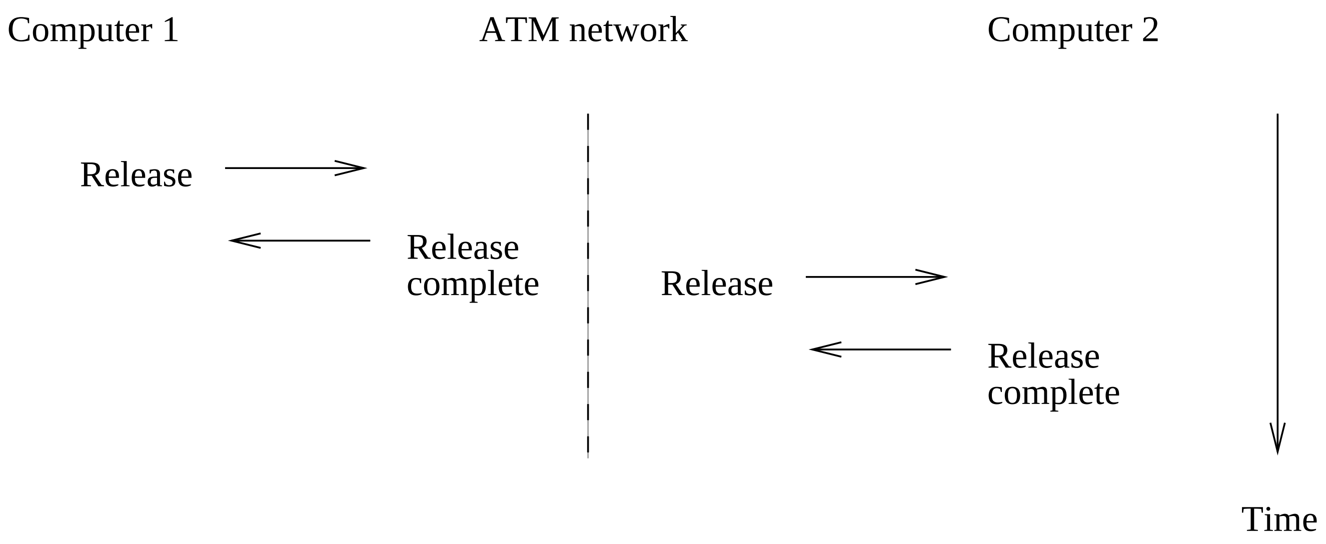

**Overall video telephony set-up**




**Implementation of video telephony channel**



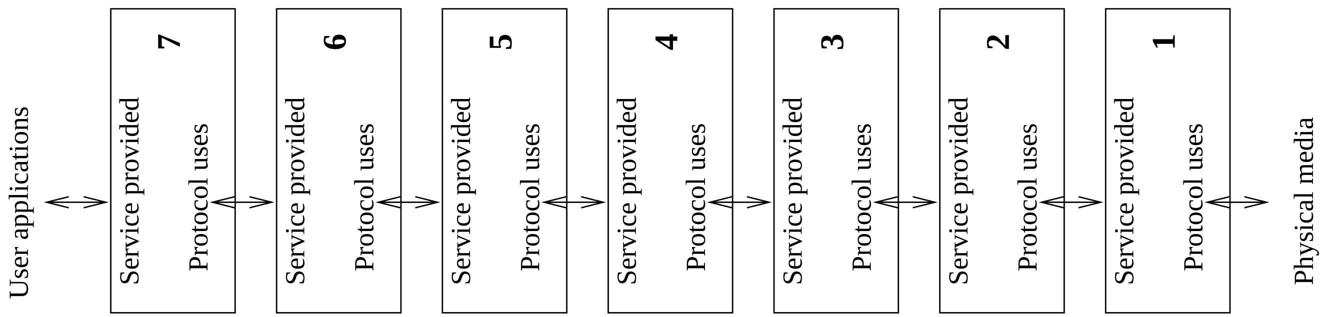

**Establishment of connection using Q.2931**



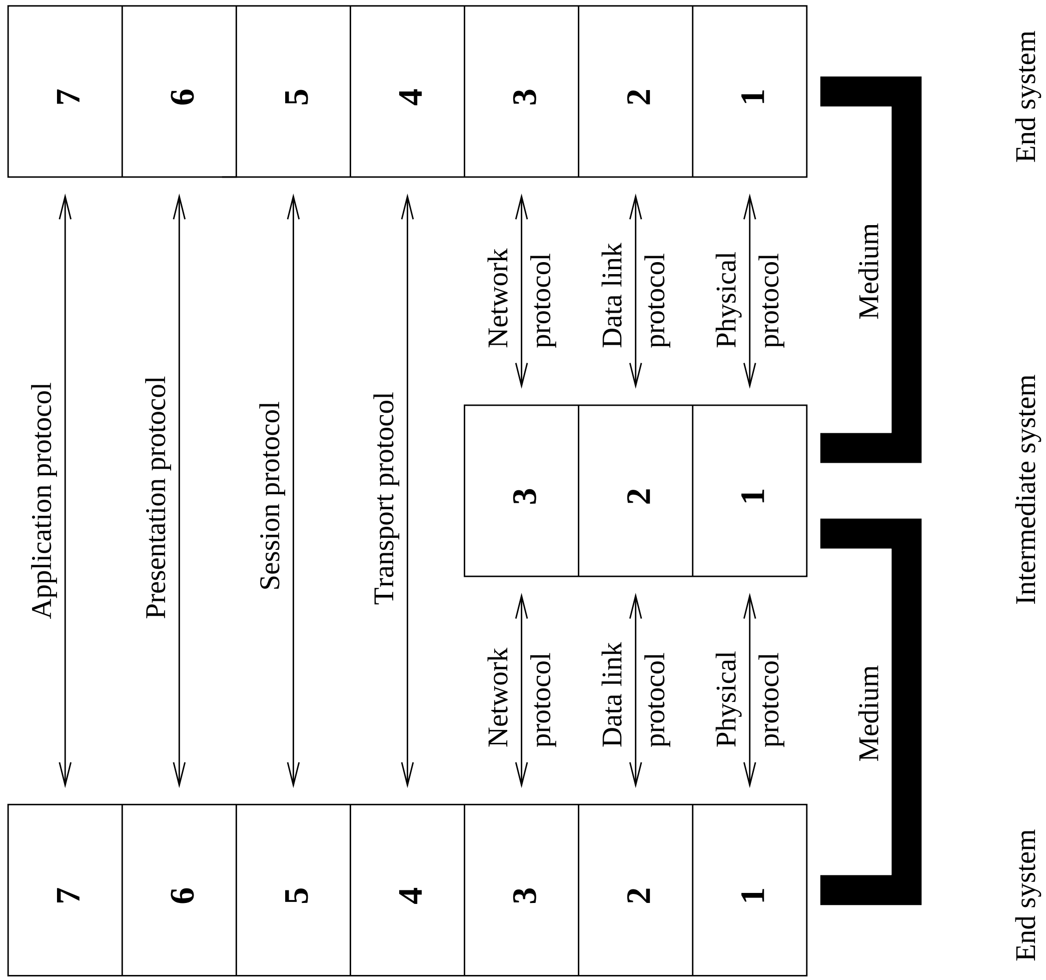

**Termination of connection using Q.2931**

| | |
|---|---|
| User information | |
| User-to-user indication | 1 byte |
| Common part indicator | 1 byte |
| Message length | 2 bytes |
| Cyclic redundancy code using CRC-32 | 4 bytes |

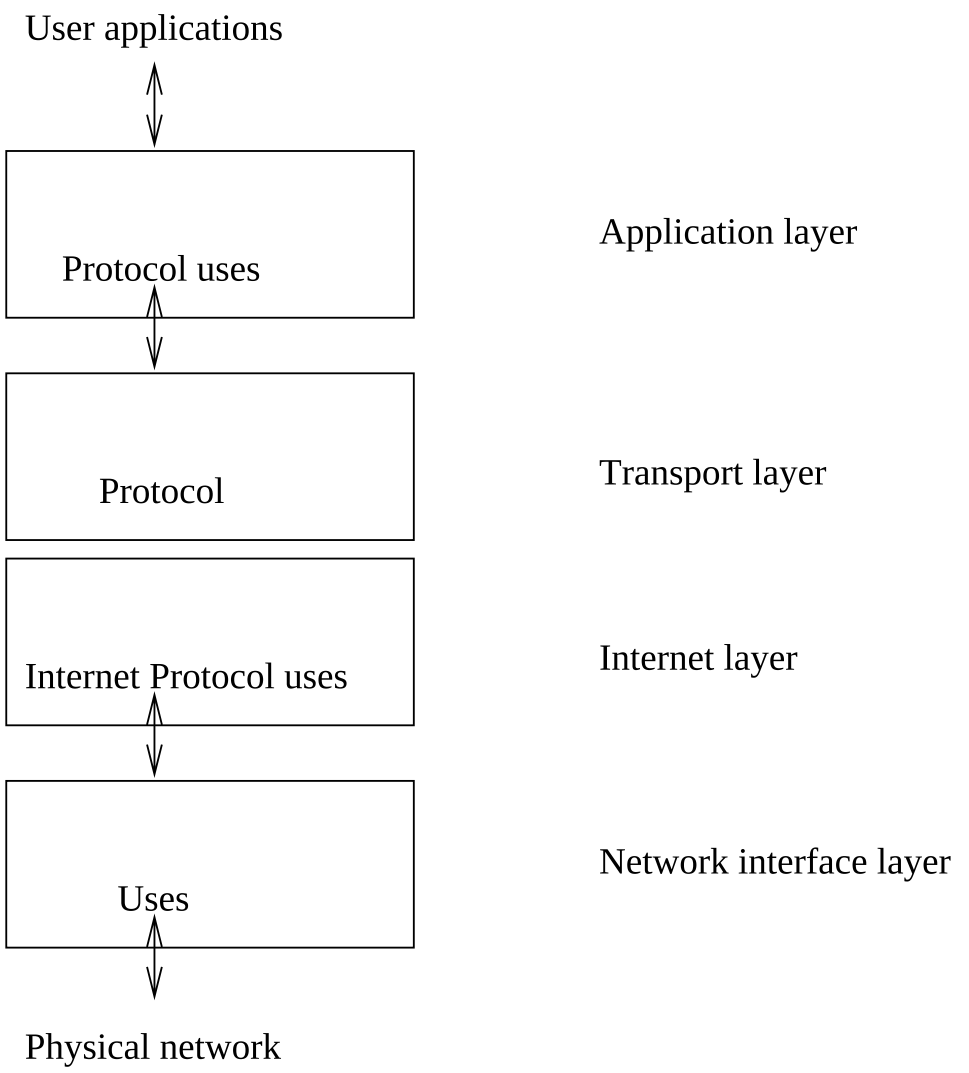
**Format of AAL5 message**



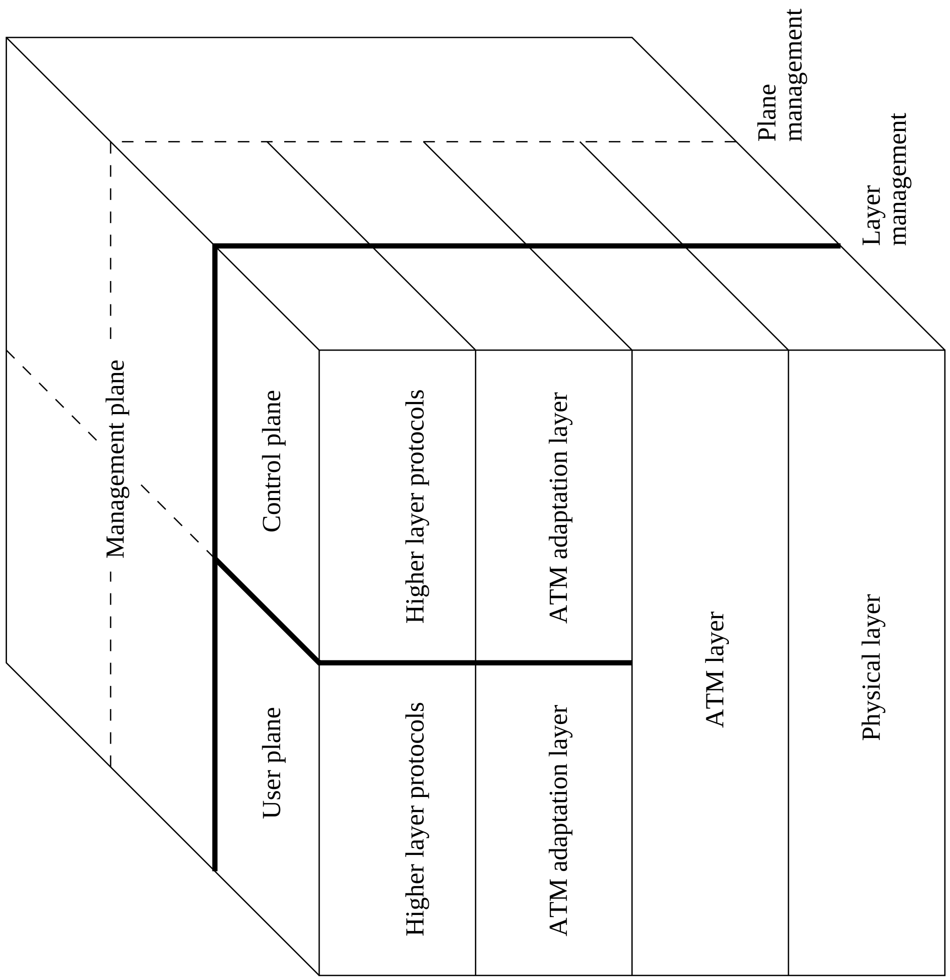

**RM/OSI layering of a communication system**



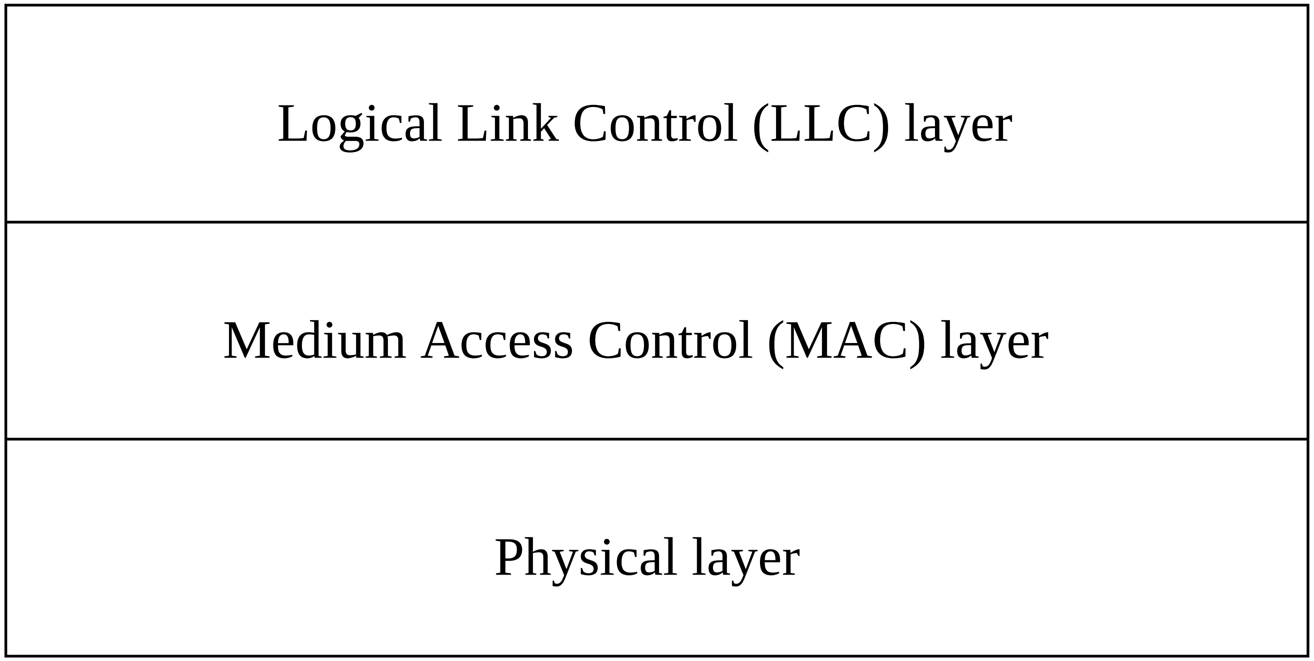

**Protocol dialogues in RM/OSI**




## Internet model layering of a communication system




ITU-T B-ISDN ATM reference model




**IEEE layering for LAN standards**


**SNA layering of a communication system**