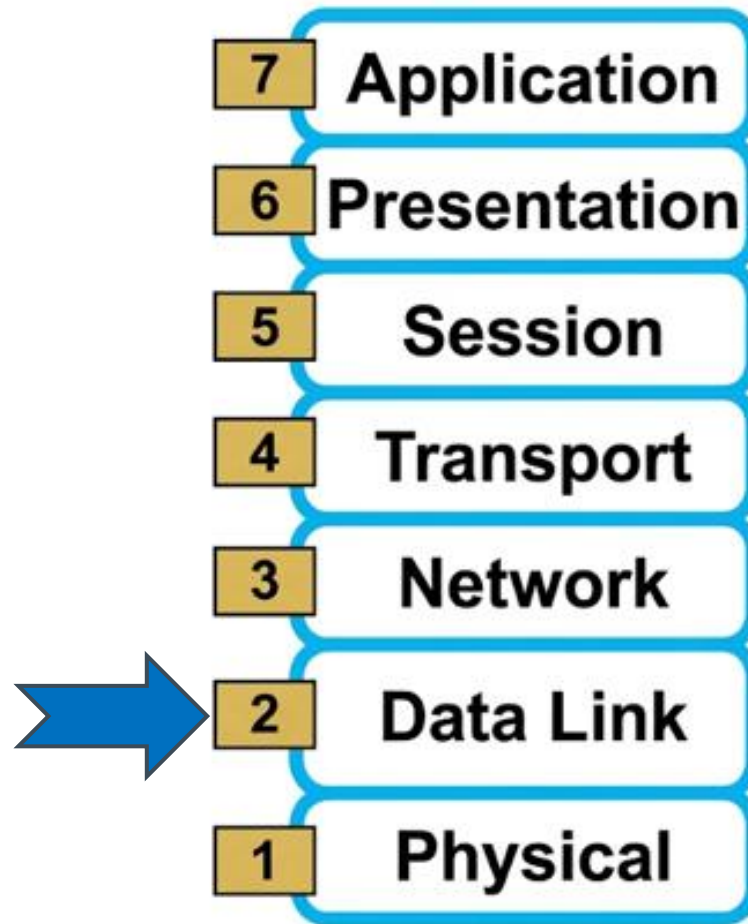


The Data Link layer

1



What are the three main roles of a data link protocol??

Role of a data link protocol

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1- Specifying the frame format

- Their delimiting

2- Validity checking

- The means of checking their validity (parity, polynomial code, etc.)
- The method for correcting detected errors.

3- Defining the rules of dialogue between the two ends:

- Flow control (checking the rate at which information is sent)
- Managing acknowledgments

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

The most common solutions for delimiting the beginning and end of a frame are:

- ☐ Delimiting using a special bit sequence
- ☐ Explicitly indicating the frame length.

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Delimiting using a specific bit sequence

- Frames with an arbitrary number of bits
- Use of a flag, start/end: 01111110
- A transparency mechanism (bit stuffing) inserts a '0' into the body of the frame after five consecutive '1's.
- On reception, the '0' must be removed after five consecutive '1's are encountered.

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Delimiting by transmitting the length of the data field

Indicate, in a specific field whose position is fixed relative to the start of the frame, the number of useful bytes contained in the frame. This technique avoids transparency issues. The frame length can be adjusted to a fixed length by adding padding bits. The field then specifies the size of the useful data carried in the frame.

Role of a data link protocol

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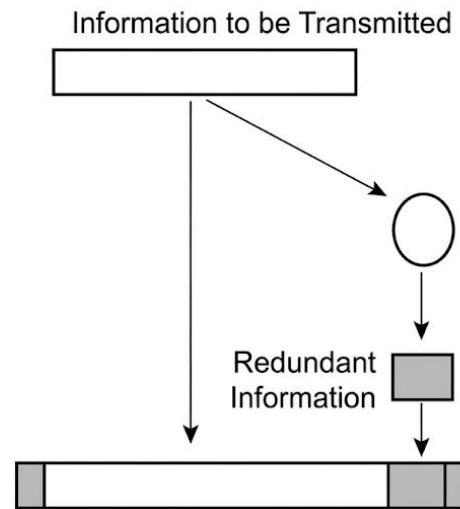
Formatting the data

Checking the validity of the transmitted information

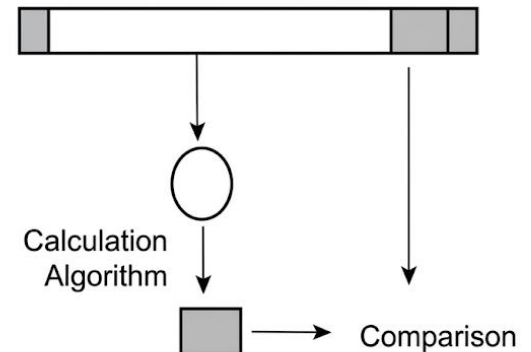
Data link operating modes

Error control consists of checking the validity of the transmitted data by adding redundancy to the transmitted information.

Calculation at Transmission



Verification at Reception



Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Error correction is done either through retransmission, or by making use of the rich redundancy information, which locates and corrects detected errors. Transmission errors can always occur in such a way that consistency still holds; in that case, we are dealing with residual errors. The residual error rate must be as low as possible, but it can never be zero on a real data link.

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Protection at the code level

This type of protection is possible when data is sent character by character: a parity bit, called vertical parity or VRC (Vertical Redundancy Check), is added to each character, calculated as follows: if the number of 1 bits in the character is even, a 0 is appended; otherwise, a 1 is appended.

For example, for the character M coded as 1001101, the parity bit is 0. It is transmitted in this order: 1001101**0**. The drawback of parity checks is that double errors are not detected.

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Protection at the frame level

Longitudinal parity check, or LRC
(Longitudinal Redundancy Check)

To improve error detection in transmissions using parity checks, longitudinal parity and vertical parity (VRC + LRC) are often combined. To do this, a code word called longitudinal parity, or LRC, is added at the end of the frame; it consists of the modulo-2 sum of all bits of the same rank.

Role of a data link protocol

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Formatting the data

Checking the validity of the transmitted information

Data link operating modes

Protection at the frame level

Longitudinal parity check, or LRC
(Longitudinal Redundancy Check)

Example: Let the sequence of characters L, 2, M to be transmitted, coded by the following values.

1 0 0 1 1 0 0 1	character L + VRC parity
0 1 1 0 0 1 0 1	character 2 + VRC parity
1 0 0 1 1 0 1 0	character M + VRC parity
0 1 1 0 0 1 1 0	LRC to add at the end of the data

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Protection at the frame level

Polynomial check, or CRC (Cyclic Redundancy Check):

Makes it possible to detect errors spanning multiple bits.

- ❖ The calculation algorithms are performed modulo 2
- ❖ Frame to transmit $\rightarrow$ polynomial $M(x)$
- ❖ Generator polynomial $\rightarrow G(x)$ of degree r
- ❖ $x^r * M(x) = G(x) * Q(x) + R(x)$
- ❖ We transmit the polynomial $T(x) = x^r * M(x) + R(x)$

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Protection at the frame level

Polynomial check, or CRC (Cyclic Redundancy Check):

Makes it possible to detect errors spanning multiple bits.

- ❖ Errors introduced by the circuit $\rightarrow$ polynomial $E(x)$
- ❖ Data received: $S(x) = T(x) + E(x)$.
- ❖ On reception, $R1(x)$ is calculated
- ❖ $x^r * S(x) = G(x) * Q1(x) + R1(x)$
- ❖ If $R1(x)$ is zero $\rightarrow E(x)$ is zero $\rightarrow 5/5$
- ❖ If $R1(x) \neq \text{zero} \rightarrow E(x) \neq \text{zero}$: received information is discarded

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Protection at the frame level

Polynomial check, or CRC (Cyclic Redundancy Check):

Let the information to be transmitted be: 11001011

$$G(x) = x^4 + x + 1$$

Required work:

- 1) Calculate $R(x)$.
- 2) Specify the information to transmit.
- 3) Confirm the correct receipt of the sent message

Role of a data link protocol

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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

Protection at the frame level

Polynomial check, or CRC (Cyclic Redundancy Check):

We transmit:

1 1 0 0 1 0 1 1	0 1 1 1
$X^4 * M(x)$	$R(x)$

On reception, we check that the remainder of the
division
by $G(x)$ is zero.

Role of a data link protocol

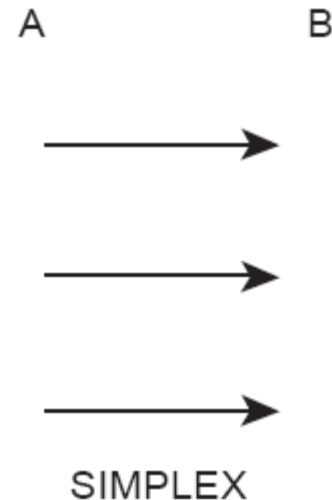
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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

The link can be operated in simplex mode, where data exchange occurs in only one direction.



Role of a data link protocol

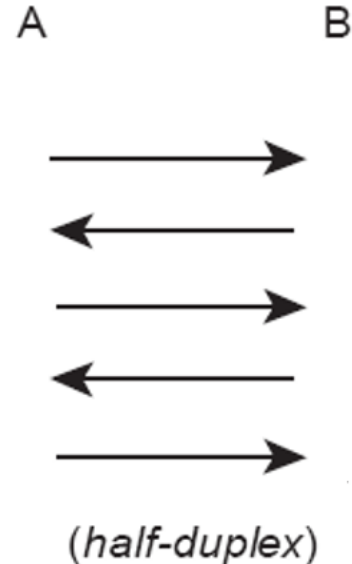
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Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

In half-duplex mode, it occurs alternately in both directions, meaning the two stations must not transmit simultaneously (otherwise there is contention).



Role of a data link protocol

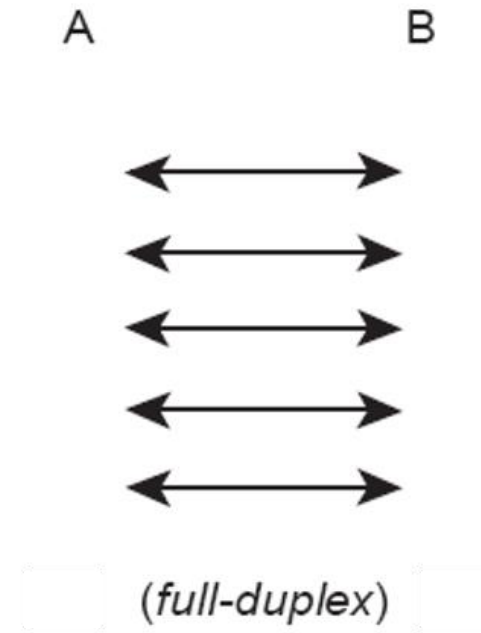
18

Formatting the data

Checking the validity of
the transmitted
information

Data link operating
modes

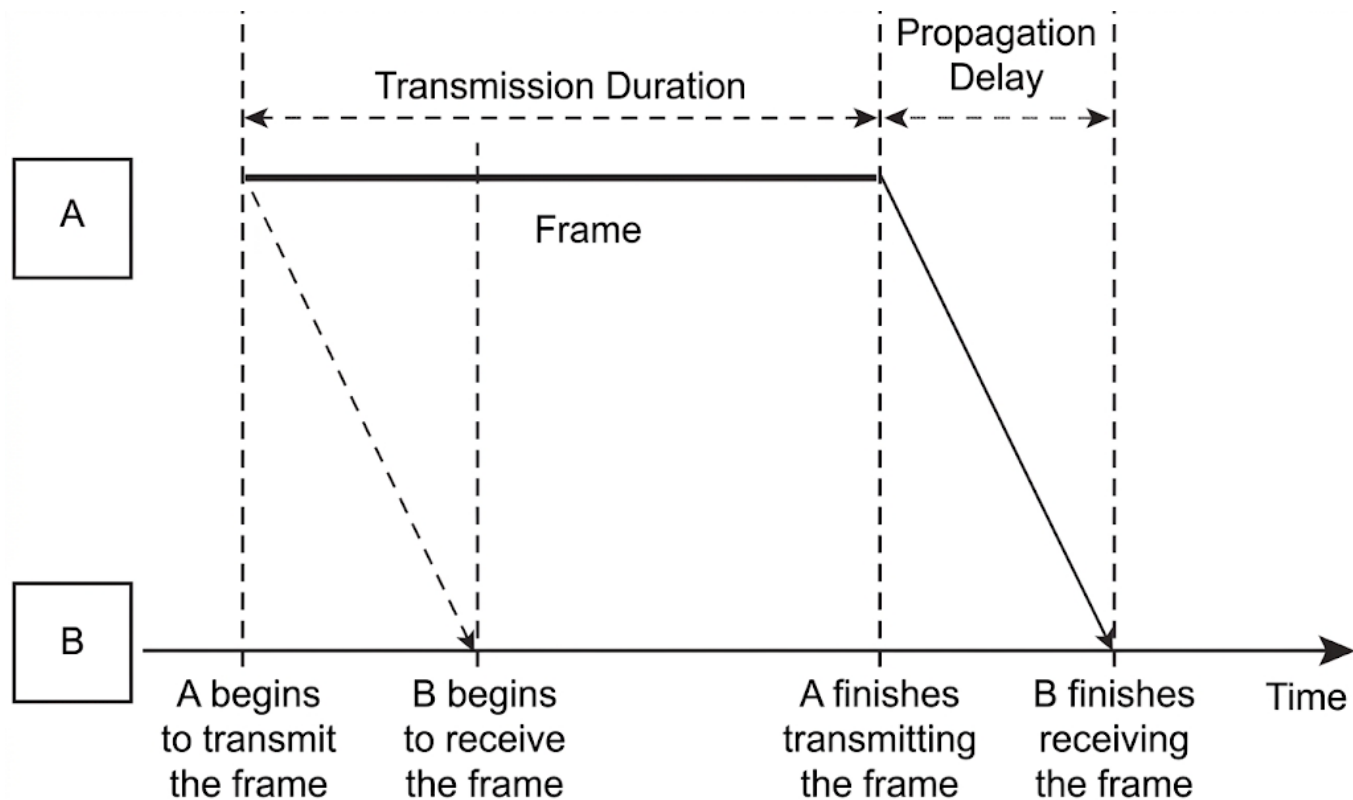
In full-duplex mode, the stations can transmit simultaneously with no restriction.



Functions of a link protocol

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Overview of data exchanges



Functions of a link protocol

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Flow control

Setting up a control mechanism for the rate at which information is sent to the receiver, by introducing supervisory frames that carry no useful information:

- ❖ RR (Receiver Ready): sent by the receiver if it is ready to accept further frames
- ❖ RNR (Receiver Not Ready): sent by the receiver if it is not ready to receive new frames. As soon as it is ready, it sends an RR frame.

Functions of a link protocol

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Acknowledgment management: Several options are possible:

- 1) When a correct frame is received, the receiver sends an acknowledgment frame, and does nothing if reception is faulty.
- 2) When a frame is received incorrectly, the receiver sends a retransmission request to the sender, and does nothing if reception is correct.

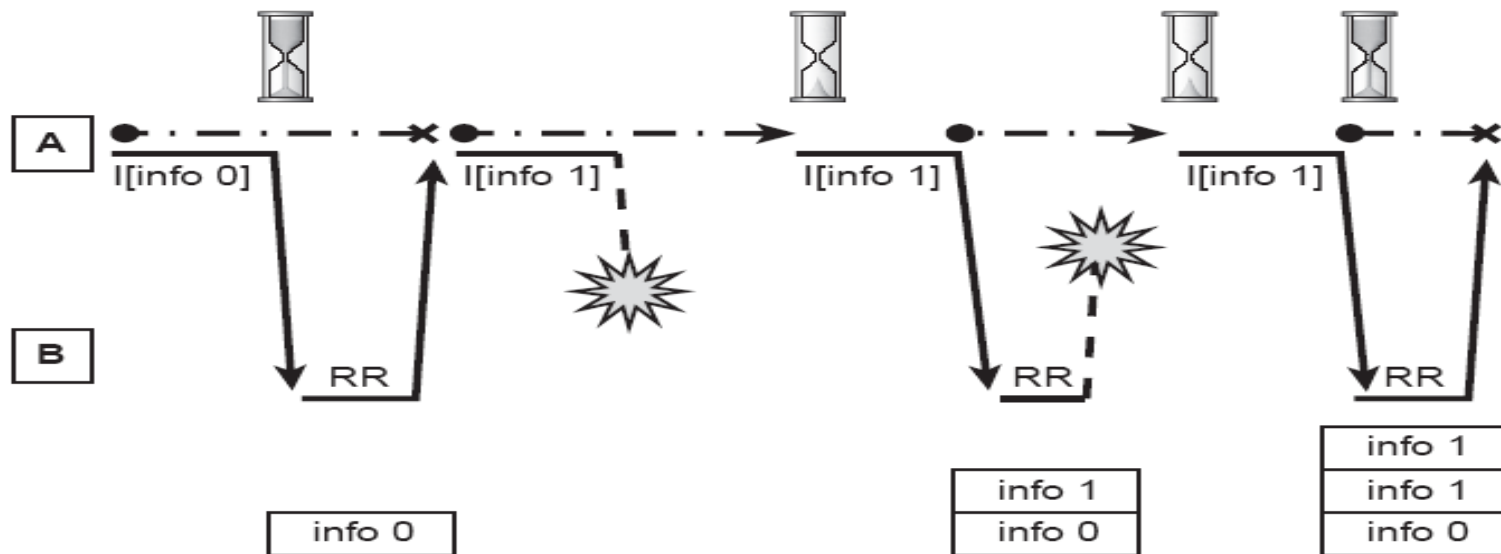
Data link protocols use strategy **1** (positive acknowledgment), by means of RR and RNR frames. The principle is as follows: when each I-frame is sent, the sender arms a timer T1, which is disarmed upon receipt of the corresponding acknowledgment. If T1 expires (with no response), the sender retransmits the frame and repeats the previous process. The number of allowed retries is limited: beyond a certain threshold, it is considered that a serious incident has occurred

Functions of a link protocol

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Acknowledgment management:

This acknowledgment mode is not satisfactory, because the transmission circuit can corrupt both the frames sent and those received.



Therefore, an additional mechanism must be introduced to distinguish between two different successive frames, by introducing a numbering field.

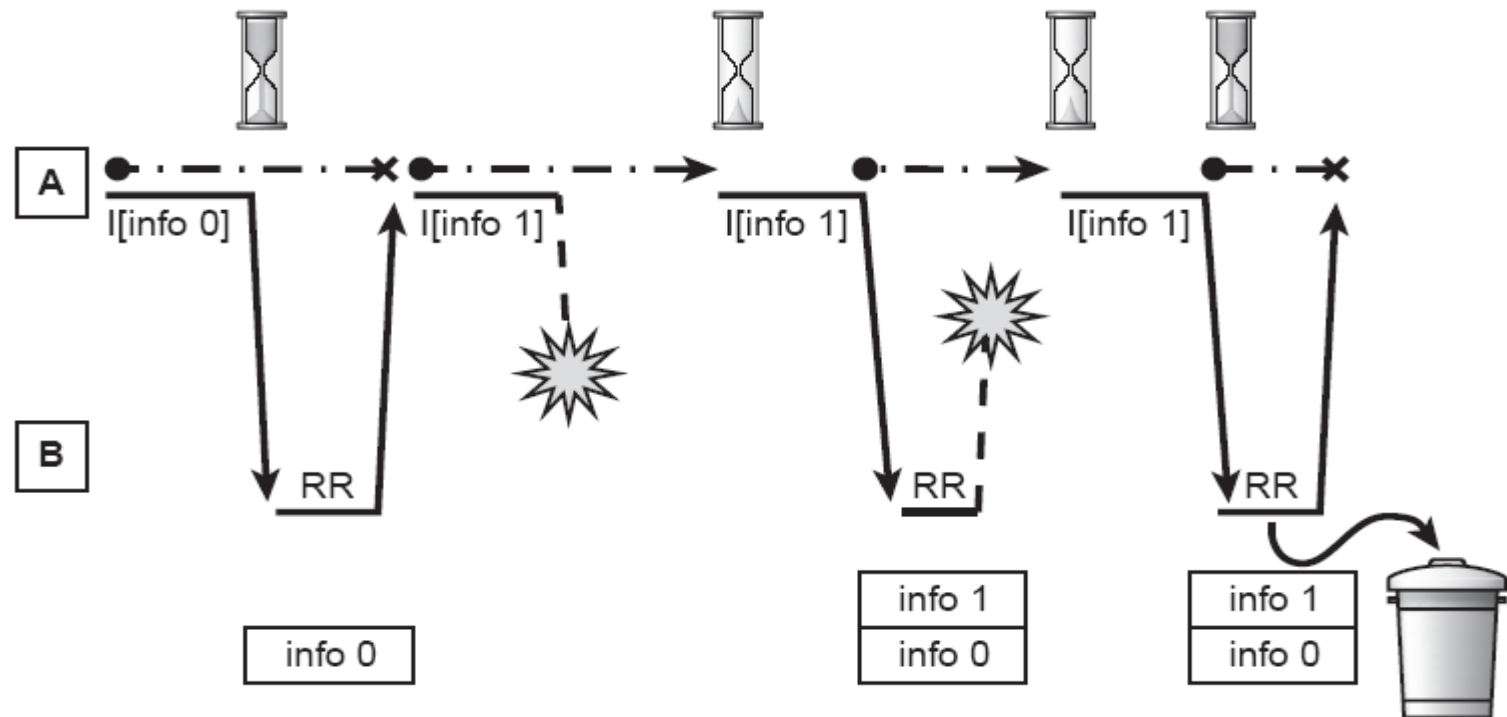
Functions of a link protocol

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Numbering of information frames / Unnumbered acknowledgment

Two frames with different numbers carry distinct data.

Use of the counter $N(S) \rightarrow$ Variable coded on a few bits is taken modulo M

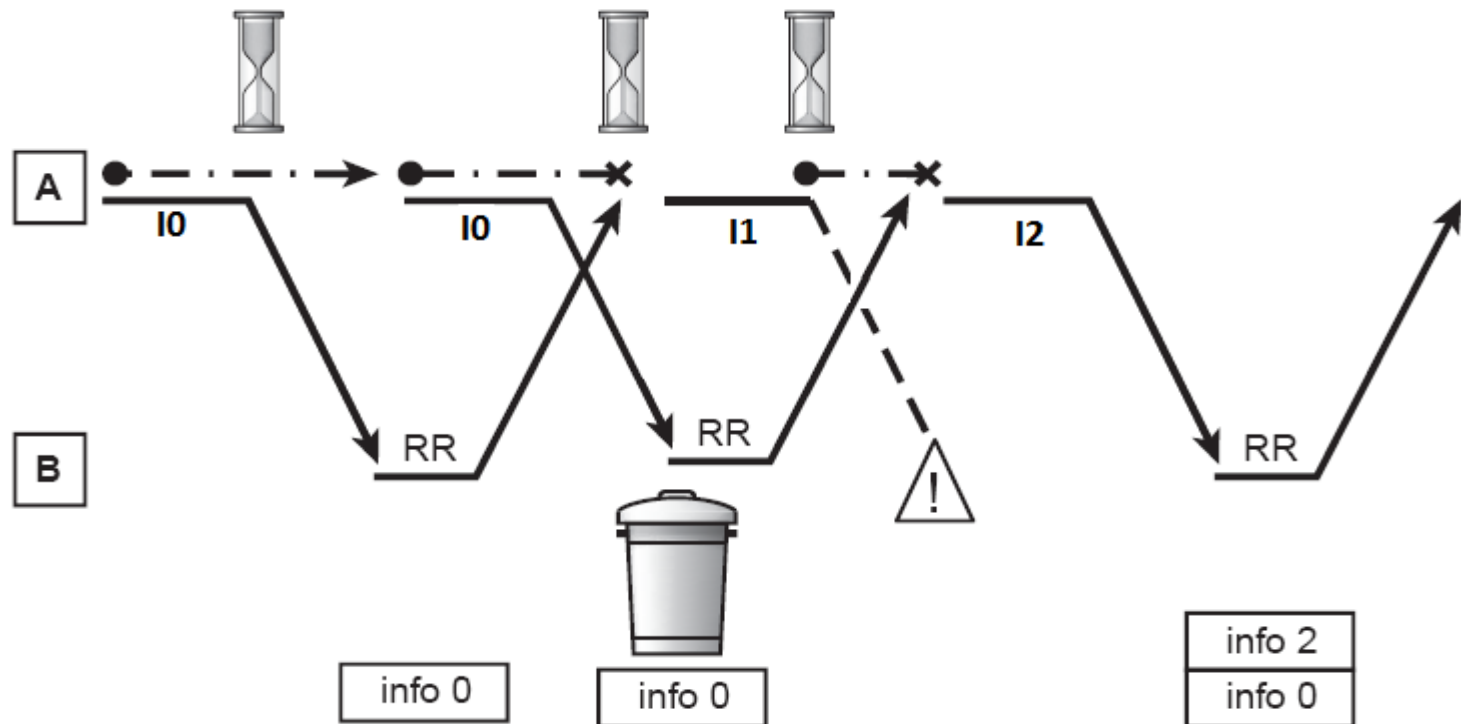


Functions of a link protocol

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Numbering of information frames / Unnumbered acknowledgment

This mechanism has a major weakness, since the value of T_1 is a critical parameter. A poor choice of value can cause the protocol to malfunction.



Functions of a link protocol

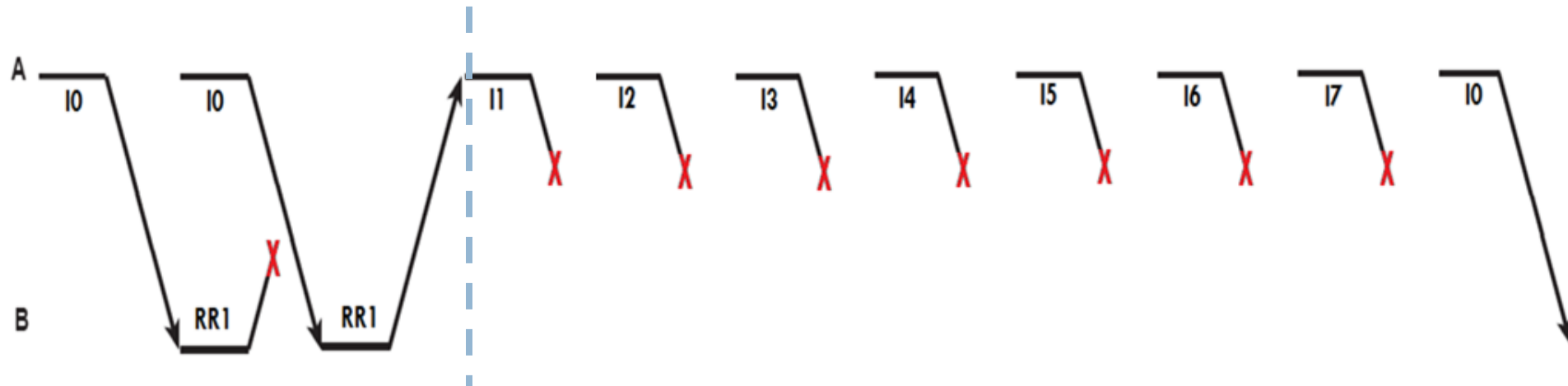
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The sliding window concept

The pipelining concept $\rightarrow$ A single acknowledgment for a set of consecutive error-free frames. The number of frames sent, denoted **k**, called the **window**.

For frame numbering modulo 8 $\rightarrow$ **K** is at most 7.

(Why not 8??)

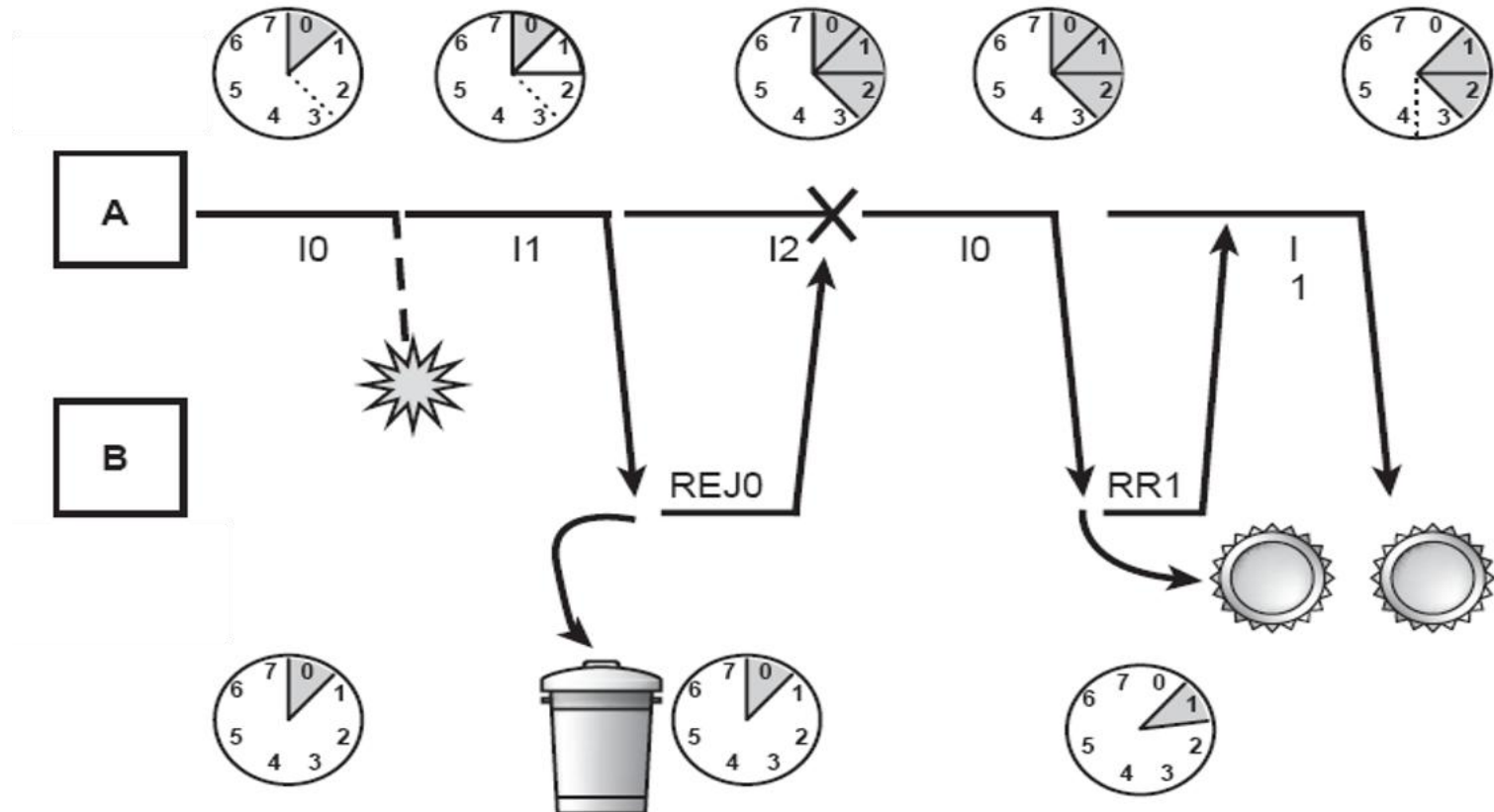


Functions of a link protocol

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Go-Back-N protocol

In the Go-Back-N strategy, a supervisory frame called REJ requests retransmission of frames starting from the erroneous frame.



Functions of a link protocol

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Piggybacking

In bidirectional exchanges, each device sends information frames that are numbered, and acknowledges the I-frames it has received. There are therefore two kinds of frames sent: I-frames and acknowledgment frames (RR, RNR, or REJ). **Piggy Backing** improves this mechanism by using I-frames to carry the acknowledgments for previously received frames.

Each I-frame has two counters, $N(S)$ and $N(R)$.

When a station has no I-frame to send, it can still use RR frames to acknowledge the traffic it receives.

End of the chapter