Datalink,
Error Detection & Correction

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Agenda

- Introduction to Data Link Layer
- Error Detection Techniques
- Error Correction Techniques
- Conclusion

What is the Data Link Layer?

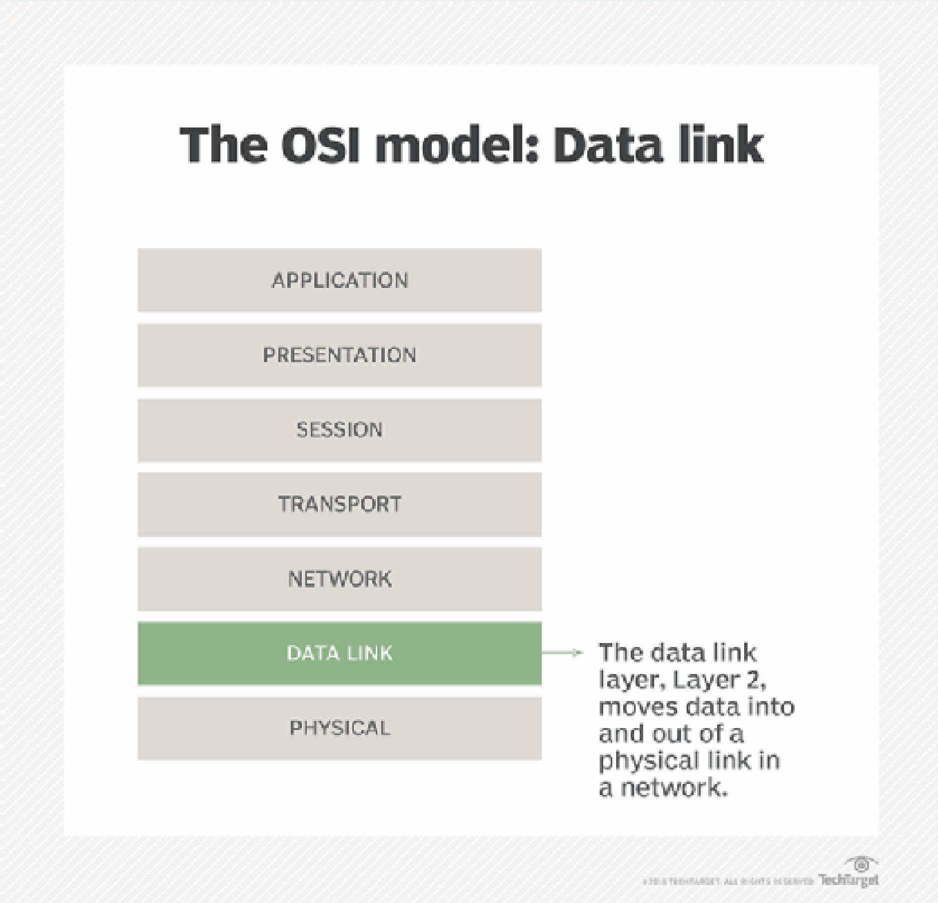

Fig. 1 The OSI Model Adapted from [1]

- 2nd layer in the OSI model
- Bridge between the physical transmission and the network layer
- Ensures reliable data communication between nodes

Key Functions of the Data Link Layer

- Framing
- Addressing
- Flow control
- Error control
- Access control

Framing Example

- E.g. sending an email

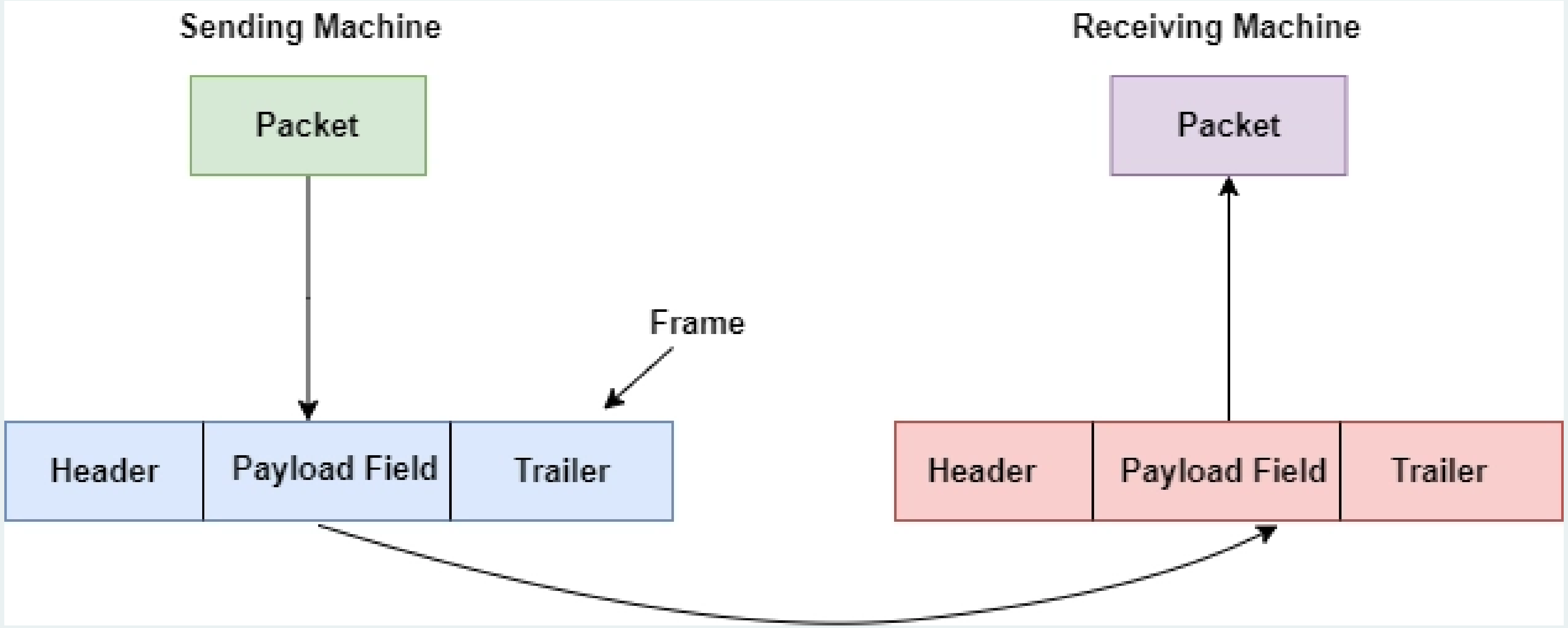

Fig. 2 Framing a Message for Transmission Adapted from [2]

Types of Data Link Protocols

Ethernet

- LANs - fast, widely-used

HDLC (High-Level Data Link Control)

- Point-to-point communication

PPP (Point-to-Point Protocol)

- direct connections (e.g. dial-up)

Error Detection

Parity Bits, Checksums, CRC

Why Error Detection Matters

- Data can get corrupted by:
  - Noise
  - Interference
  - Timing issues

Error Detection ensures data integrity

Errors

Change of one or more bits in a transmitted block of data.

Single-Bit Errors

- Isolated error (only one bit and no nearby bits)
- White noise

Burst Errors

- Contiguous sequence of bits in which the 1st and last and some between them are received wrong
- Impulse noise

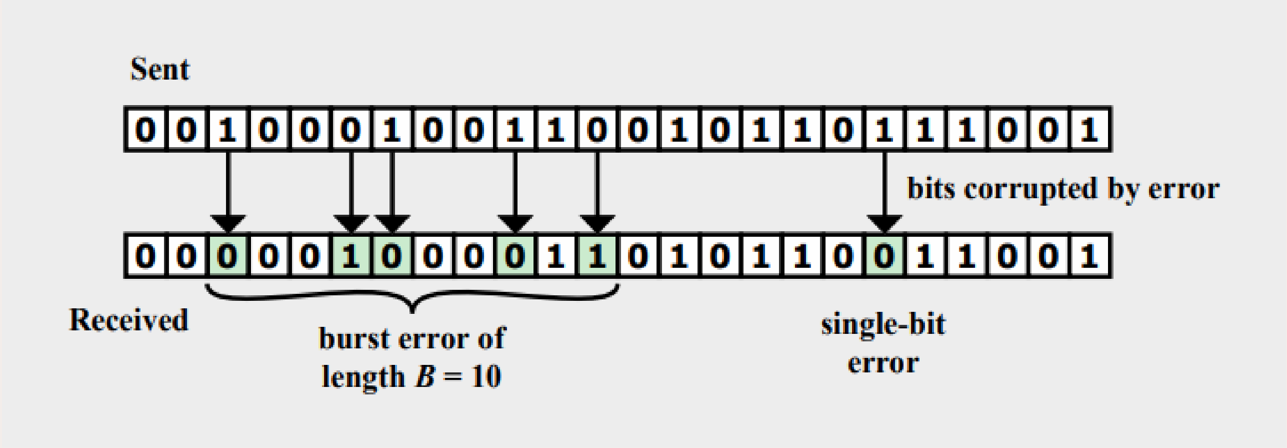

Fig. 3 Single-Bit versus Burst Errors Adapted from [4]

1) Parity Bits

- Append a parity bit to the end of the block of data
- Value of parity bit = selected for even or odd parity

e.g. 10110011 > 10110011<u>1</u>

Even Parity

- Even number of 1s
- For synchronous transmission

Odd Parity

- Odd number of 1s
- For asynchronous transmission

1) Parity Bits | 2D Parity Scheme

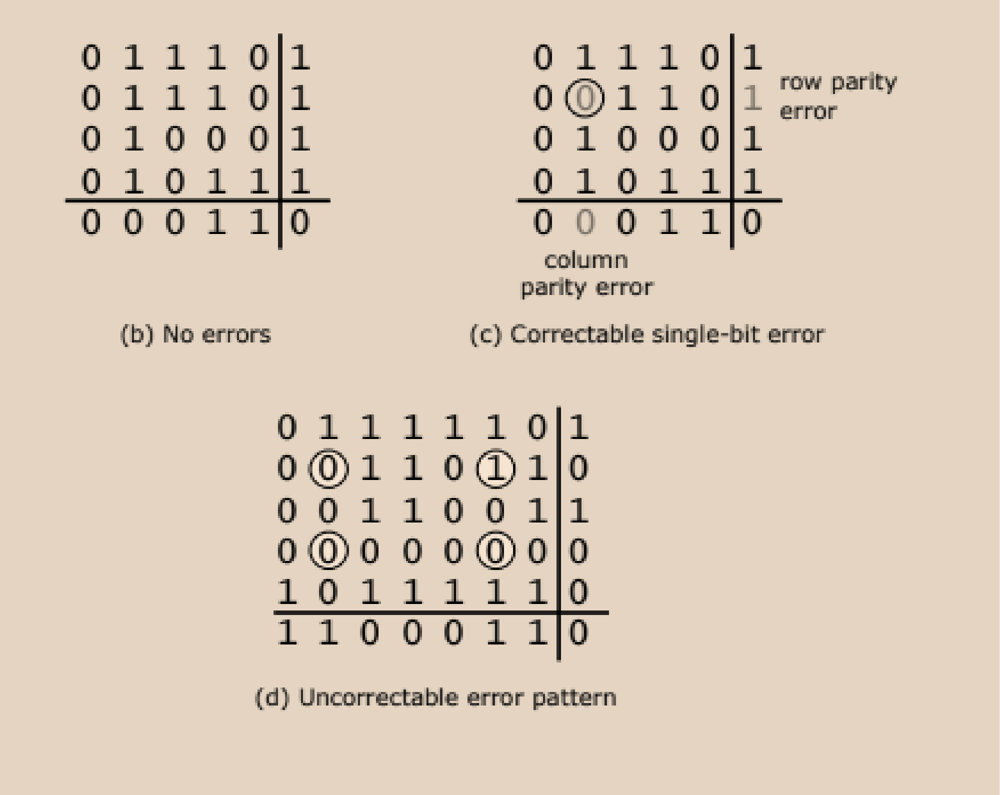

Fig. 4 A Two-Dimensional Even Parity Scheme Adapted from [4]

- More robust
- Data bits arranged in a 2D array
- Append an even parity bit to each row and column
- Overall parity bit completes the matrix
- Able to locate error at the intersection of the parity bits and correct it

2) Checksums

Partial sum	0001 F203 F204
Partial sum	F204 F4F5 1E6F9
Carry	E6F9 1 E6FA
Partial sum	E6FA F6F7 1DDF1
Carry	DDF1 1 DDF2
Ones complement of the result	220D

(a) Checksum calculation by sender

Partial sum	0001 F203 F204
Partial sum	F204 F4F5 1E6F9
Carry	E6F9 1 E6FA
Partial sum	E6FA F6F7 1DDF1
Carry	DDF1 1 DDF2
Partial sum	DDF2 220D FFFF

(b) Checksum verification by receiver

Fig. 5 Checksum: Calculating the Result Adapted from [4]

- Adding all data values and sending the result with the transmission data
- Used in TCP/IP
- Ones-complement:
  - Result = original + complement

3) Cyclic Redundancy Check (CRC)

- Binary division
- Data as a polynomial divided by another predefined polynomial
- Detects burst errors better than parity bits and checksums

1) Modulo 2 Arithmetic
2) Polynomials
3) Digital Logic

Error Correction

ARQ, FEC, Hamming Code

1) Automatic Repeat reQuest (ARQ)

- Feedback-based (retransmission if errors detected)

Stop-and-Wait	• sender waits for ACK before retransmission
Go-Back-N	• Sender can send several frames before needing ACK • Go back if error is found
Selective Repeat	• Only erroneous frames are resent • More efficient

2) Forward Error Correction (FEC)

- Sender adds redundancy so receiver can correct errors
- NO NEED FOR RETRANSMISSION
- Real-time applications
  - Video streaming
  - Satellite communication

Fig. 6 FEC Satellite Communication Adapted from [6]

3) Hamming Code

- Example of FEC
- Adds parity bits to positions that are powers of 2
- Detects and corrects single-bit errors
- Receiver performs a calculation to find corrupted bit

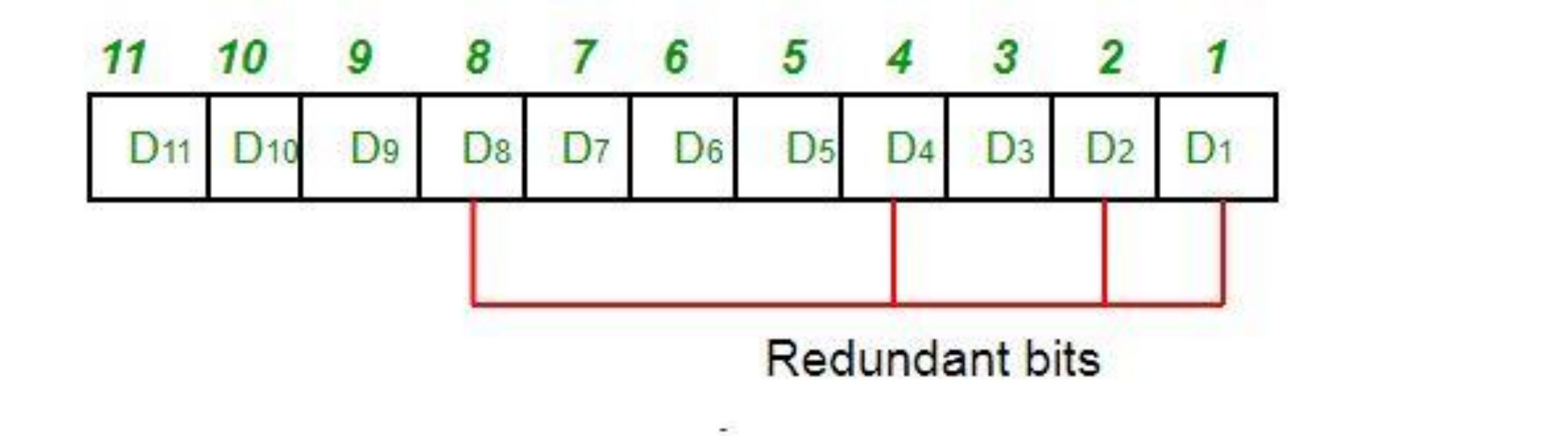

Fig. 7 11-Bit Hamming Code Set-Up Adapted from [3]

3) Hamming Code Example | Encoding

7	6	5	4	3	2	1
1	0	0	P_3	1	P_2	P_1

Data bits: 1001

Parity bits (even parity):
P_1 = Check 1, 3, 5, and 7
P_2 = Check 2, 3, 6, and 7
P_3 = Check 4, 5, 6, 7

3) Hamming Code Example | Encoding

7	6	5	4	3	2	1
1	0	0	1	1	0	0

Data bits: 1001

<u>Parity bits (even parity):</u>
P_1 = Check 1, 3, 5, and 7
P_2 = Check 2, 3, 6, and 7
P_3 = Check 4, 5, 6, 7

7-bit code to be transmitted: 1001100

3) Hamming Code Example | Decoding

7	6	5	4	3	2	1
1	0	0	0	1	0	1

Parity bits (even parity):
P_1 = Check 1, 3, 5, and 7
P_2 = Check 2, 3, 6, and 7
P_3 = Check 4, 5, 6, 7

7-bit code received: 1000101
Data bits received: 1001
Actual data bits transmitted: 1011

P_3	P_2	P_1
1	0	1

Real-World Applications

Error detection and correction are crucial in:

- Wi-Fi
- Satellite communication
- Video streaming and video calls
- CDs and DVDs
- Texting applications (WhatsApp)

Future Trends

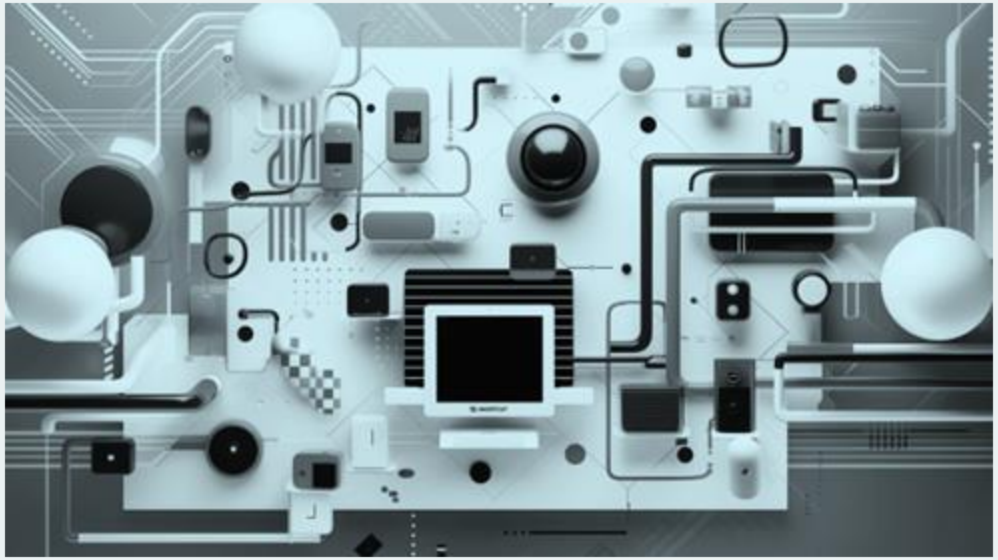

Fig. 8 Future Technology Trends Adapted from [7]

- AI-assisted error correction
- Quantum error correction
- Improved wireless protocols

Conclusion

Data Link Layer

- Reliable, structured delivery between nodes

Error Detection

- Parity
- Checksum
- CRC

Error Correction

- ARQ (retransmission)
- FEC (redundancy)

Thank You

References

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