# IEEE 802.3ah

## FEC Framing in EFM

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# Scope

- FEC for EFM
- Merging FEC with Ethernet packet format in a transparent way
  - Defining layering with FEC
  - Defining FEC packet format

# Motivation

- FEC as the cost effective method to meet reach/split targets using low-cost optics:
  - Split limit case - improve link budget
  - Distance limit case - extend MPN-limited uplink reach
- Using RS (255,239) octet based code
- Additional ~4dB gain

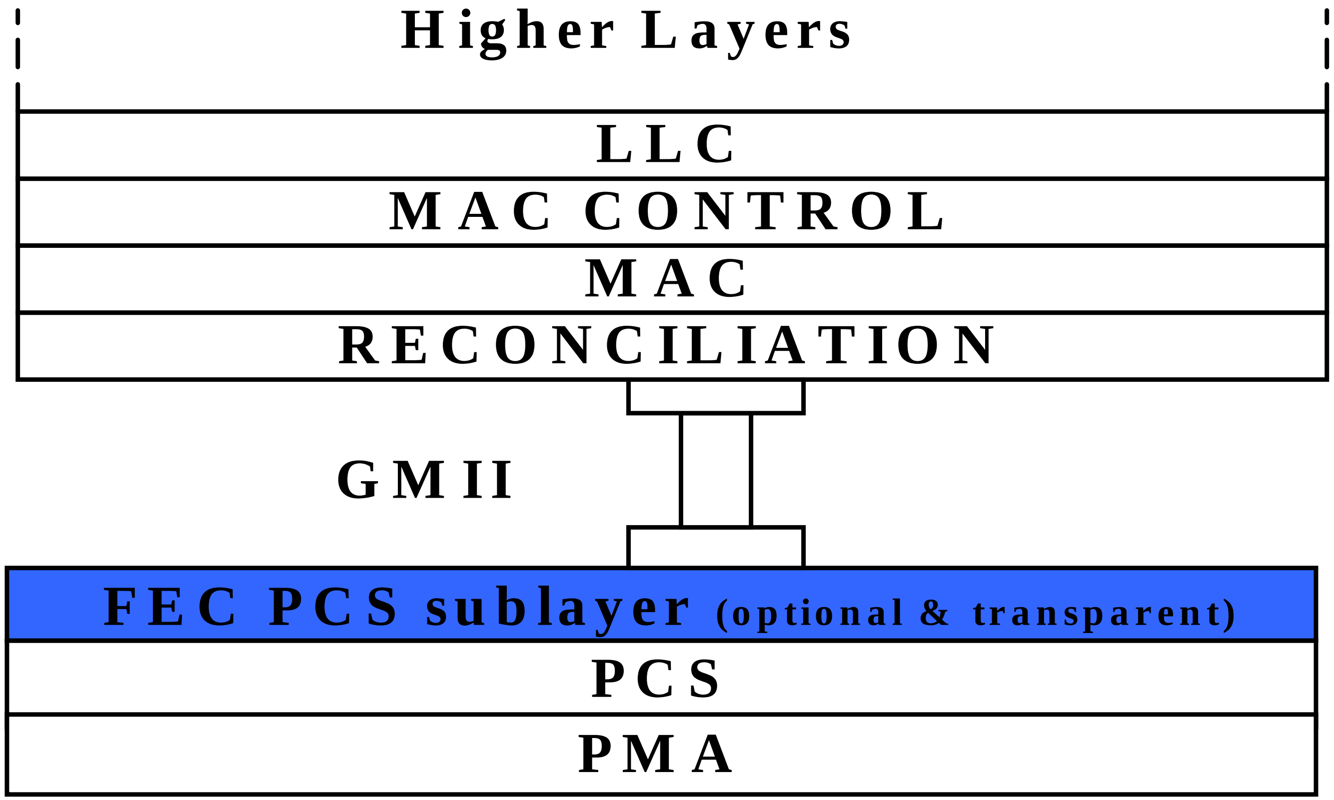
# Compatibility

- Need to support and fit in with current Ethernet devices
- Compatibility with data format
  - Stream of an FEC coded data should be understood by current non FEC Ethernet devices and not cause them errors
- Ability to add FEC functionality externally

$$\Downarrow$$

- Optional and transparent use of FEC

# Adding FEC to the Ethernet layers



# Basic Principles of Operation

- Keeping the packet structure
  - Parity check bytes should be added at the end of the packet - IPG stretching
- Using systematic code – visible data bytes
- FEC is coded before the 8B/10B code

$$\Downarrow$$

- Non FEC devices observes a regular Ethernet packet
  - Detecting False_Carrier_detect at parity bytes time (RX_ER is asserted)

# Ethernet FEC Packet Format

- All of the packet is encoded including preamble, address and FCS
- Parity check bytes added at the end of the packet
- Shortened last frame – virtually zero padded
- Additional delay of a packet size – up to 12usec Net Round trip delay is 100usec for 10Km
- Special 10B code words are not FEC coded – using a sequence of symbols to add immunity

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Start Symbols | Preamble | SFD | Header | Data: 46-1500 byte | FCS | Stop Symbols | parity bytes | Stop Symbols | IPG |

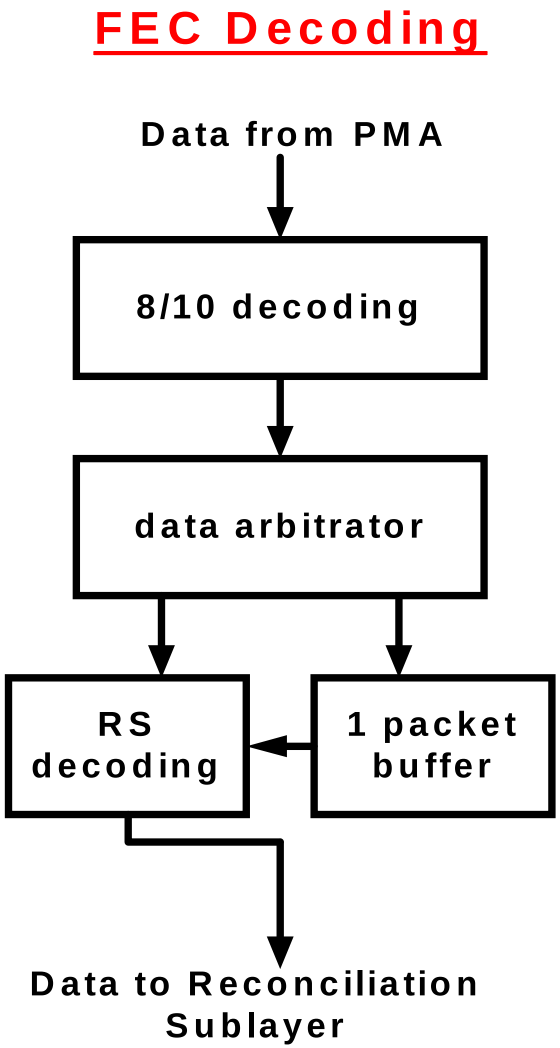
# Protecting Special 10B words

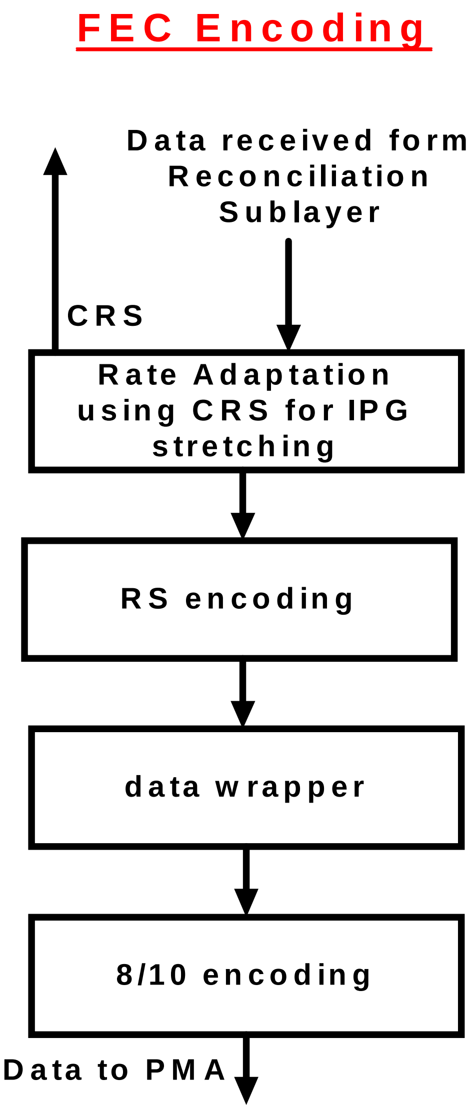
- Special 10B words are used for packet start, packet stop and comma detection
- Extend the words to a sequence and protect with correlation of sequence
- Should be transparent to FEC disabled state machine (Also assigned as False_carrier_detect)
  - /K28.5/ - comma is in the idle word and is duplicated many times – remains the same
  - /S_fec/ - Start_of_Packet - ex: /R/R/K28.5/D21.2/S/
  - /T_fec/ - End_of_Packet (and end of parity check bytes) - ex: /T/R/K28.5/D21.2/T/R/

# FEC Layering Mechanism

- For the reconciliation layer – IPG stretching
- Additional Idles inserted in reception
- IPG stretching in transmission can be achieved in 2 ways
  - Open loop – Adapting MAC rate as in 10G
  - Close loop – Exporting a signal to the Reconciliation layer
    - Use of something like the CRS or COL lines of half duplex mode

# Data Flow for FEC Sublayer



# Effect of FEC Data on non FEC devices

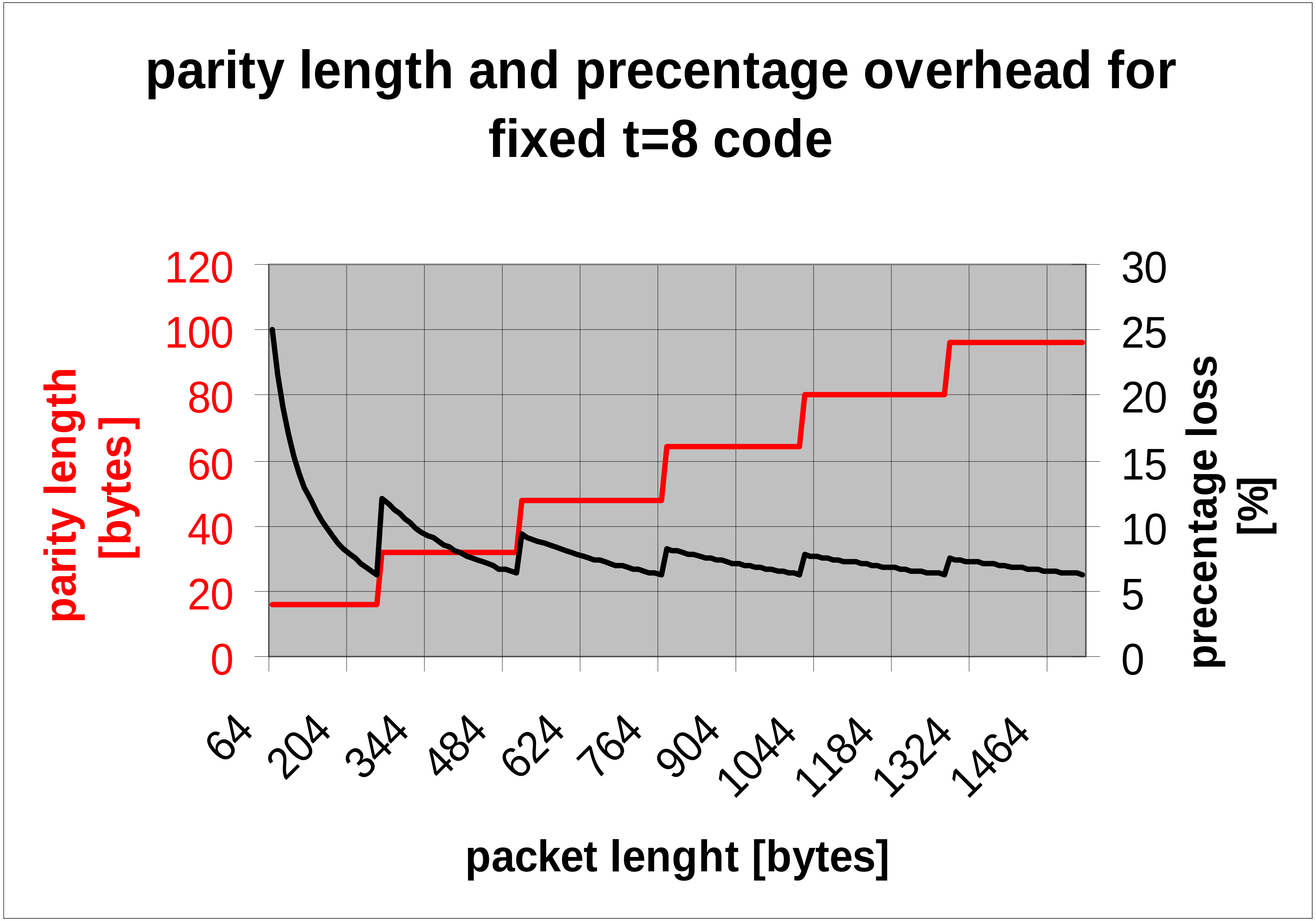
- Compatibility of data stream is relevant for receiving only
- For non-FEC devices the Packet is transparent
- During Parity check bytes and start & stop sequences, RX_ER is asserted -Transmitted as False_carrier_detect mode
- The False_carrier_detect mode is ignored by Reconciliation Layer

# Compatibility with Current devices

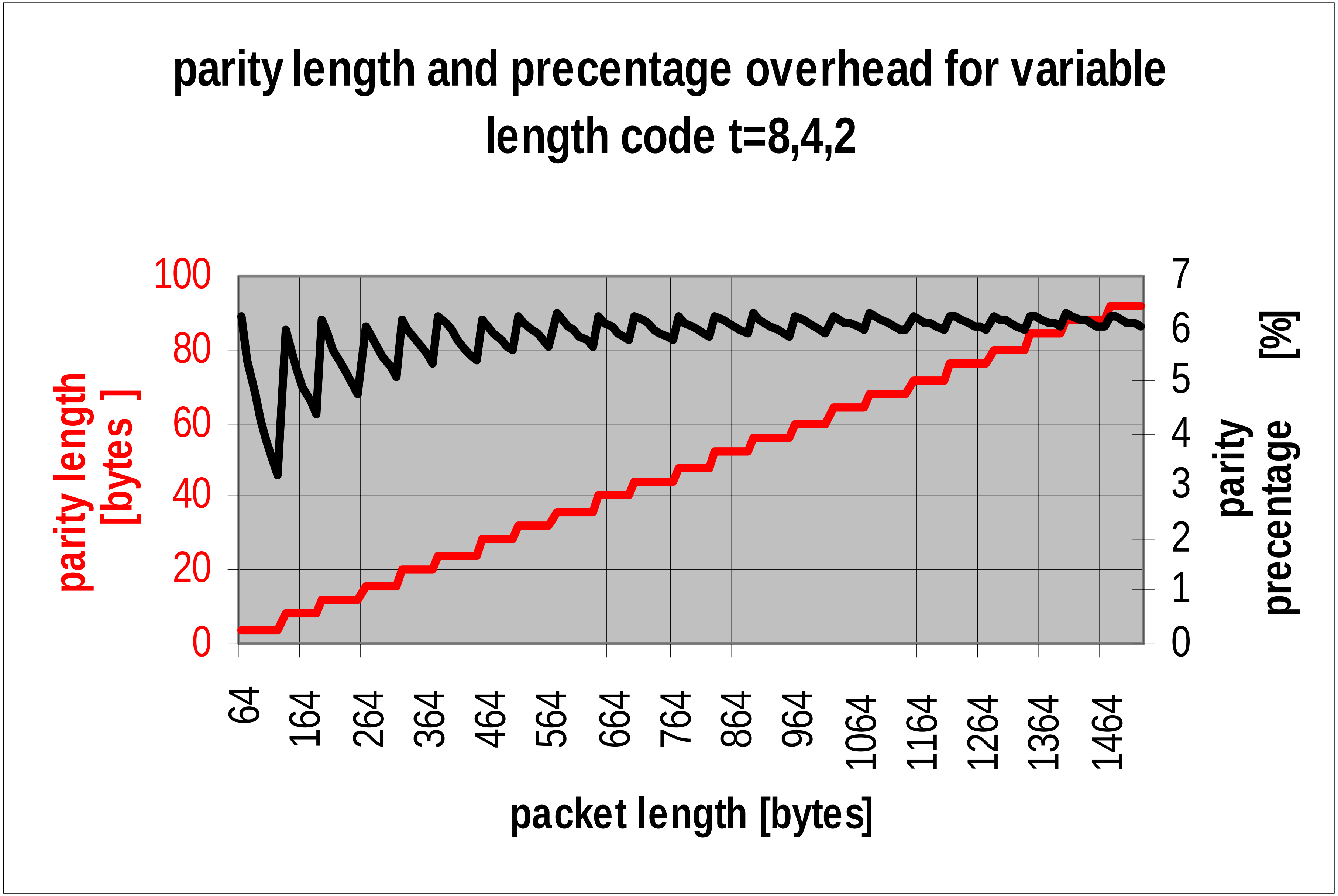
- FEC may be added after non-FEC devices using an FEC component which:
- On transmission
  - Detects the packet boundaries
  - Encode FEC and add parity bytes at the end of the packet
  - Has a adaptation FIFO – uses pause flow control to enable/disable data from current device
- On reception
  - Decodes FEC
  - Pad Idles

# FEC Rate Efficiency

- 16 Parity check bytes are added for each 255 bytes
- Additional bytes: $\left(2 \cdot \mathbf{t} \cdot \left\lceil \frac{64}{\mathbf{k}} \right\rceil\right)$ to $\left(2 \cdot \mathbf{t} \cdot \left\lceil \frac{1518}{\mathbf{k}} \right\rceil\right)$
- FEC can overwrite current IPG
- Can achieve better efficiency by using t=2,4 code for short packets



parity length and precentage overhead for fixed t=8 code
parity length [bytes]
120
100
80
60
40
20
0
30
25
20
15
10
5
0
precentage loss [%]
64
204
344
484
624
764
904
1044
1184
1324
1464
packet lenght [bytes]


parity length and precentage overhead for variable length code t=8,4,2
parity length [bytes ]
100
80
60
40
20
0
7
6
5
4
3
2
1
0
parity precentage [%]
64
164
264
364
464
564
664
764
864
964
1064
1164
1264
1364
1464
packet length [bytes]

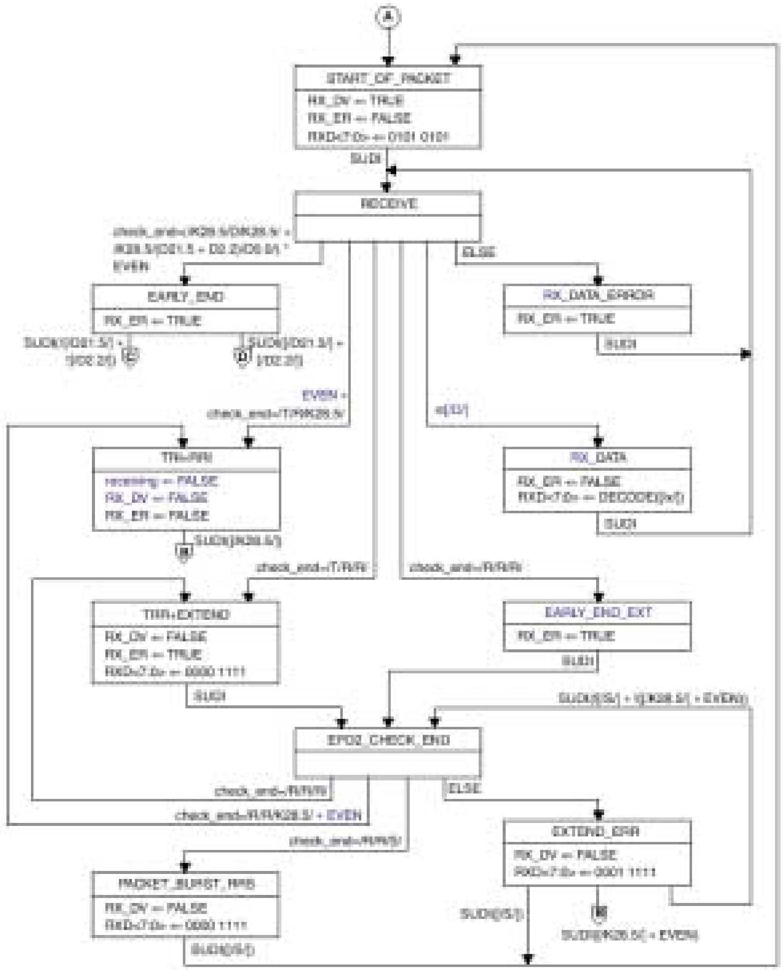
# Conclusion

- Combining FEC with the Ethernet packet
- Need to support current Ethernet devices
- Optional and transparent use of FEC
- Parity check bytes at the end of the Ethernet packet
- IPG stretching mode

# Appendix

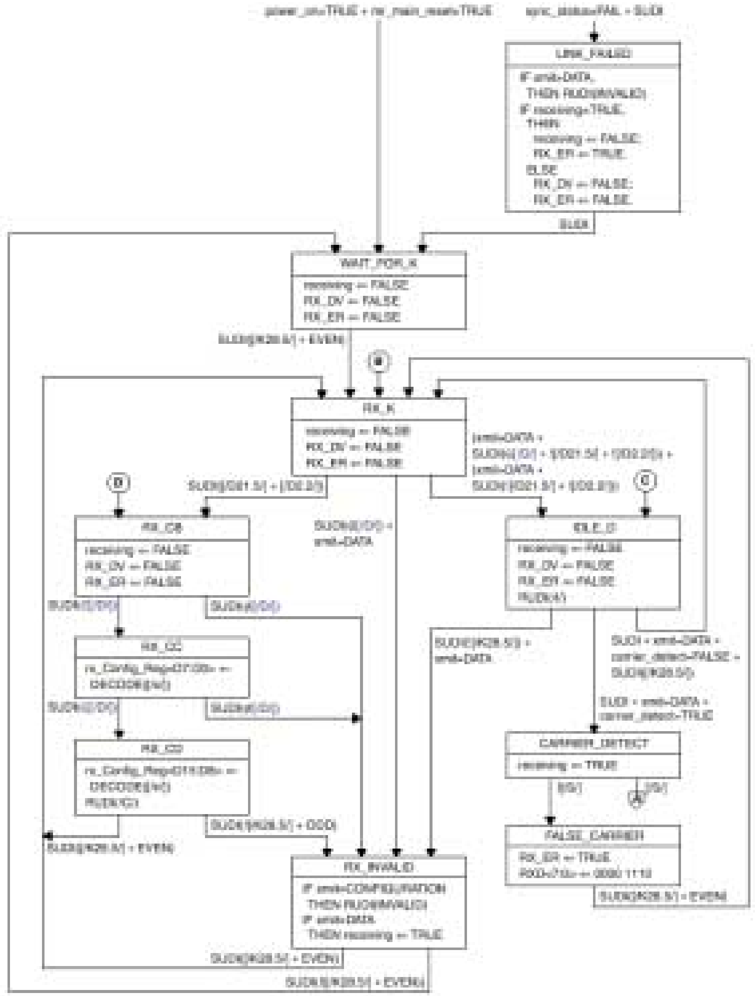
- State machine of current PCS
- FEC data stream through current PCS RX. state machine
- FEC data stream through FEC PCS RX. state machine
- FEC Rx state machine

# PCS Rx State Diagram



NOTE—Outgoing arcs leading to labeled polygons flow offpage to corresponding incoming arcs leading from labeled circles on Figure 36–7a, and vice versa.

**Figure 36–7b—PCS receive state diagram, part b**



NOTE—Outgoing arcs leading to labeled polygons flow offpage to corresponding incoming arcs leading from labeled circles on Figure 36–7b, and vice versa.

**Figure 36–7a—PCS receive state diagram, part a**

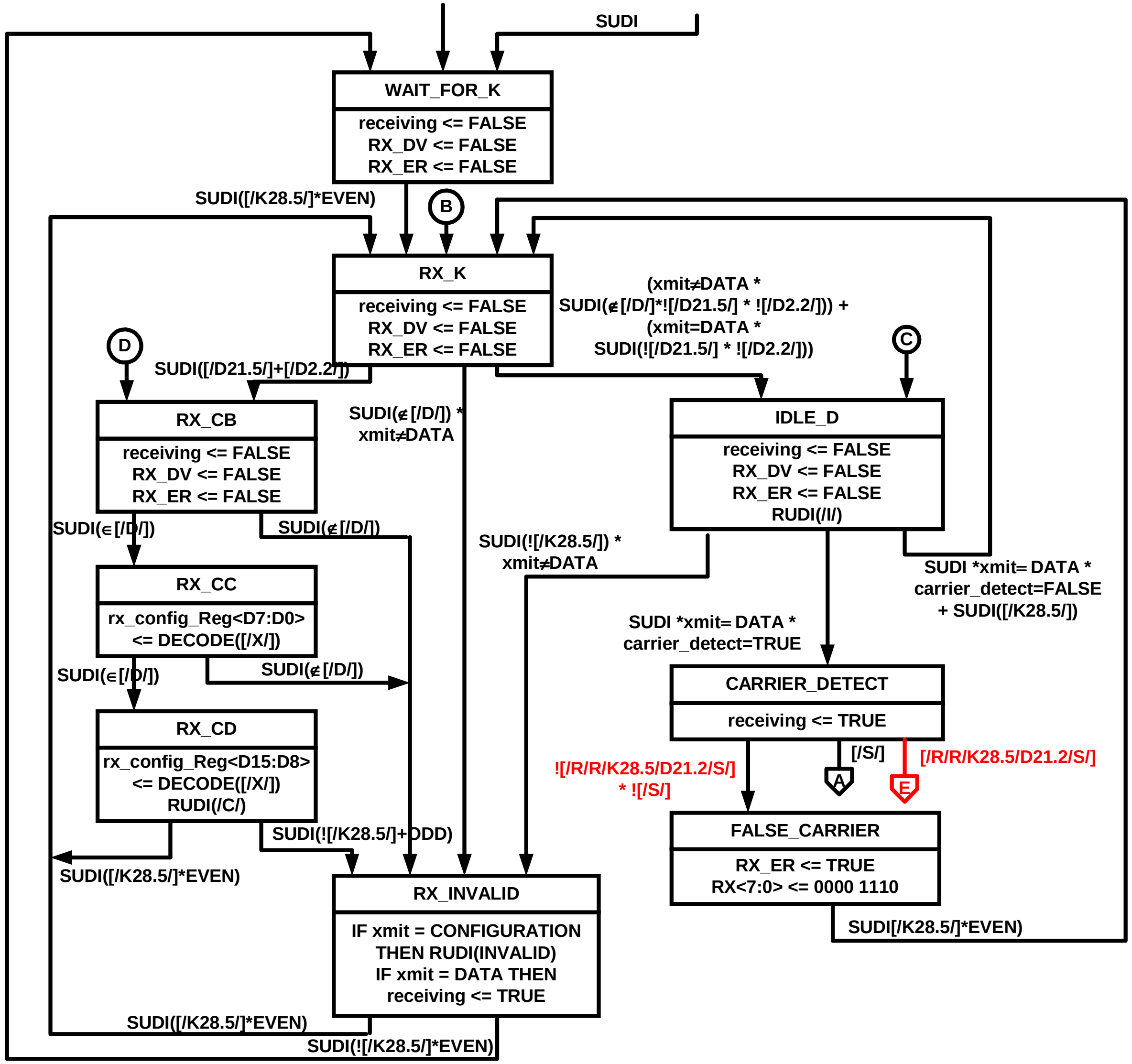
# PCS signaling for Non FEC device with FEC coded data

| Comments | 10B stream | Carrier Detect | Receiving | RX_DV | RX_ER | RXD<7:0> |
|---|---|---|---|---|---|---|
| **IDLEs** | **/IDLE/** | | FALSE | FALSE | FALSE | RUDI(/I/) |
| **Special Packet start** | **/R/R/** | TRUE | TRUE | FALSE | TRUE | 0000 1110 |
| | **/K28.5/D21.2/** | FALSE | FALSE | FALSE | FALSE | RUDI(/I/) |
| **Packet Start** | **/S/** | TRUE | TRUE | TRUE | FALSE | 0101 0101 |
| **Data** | **/D/D/** | (All error states as before) | | | FALSE | DECODE[/x/] |
| **Packet End** | **/T/R/K28.5/** | | FALSE | FALSE | FALSE | |
| **Special Packet end** | **/D21.2/** | FALSE | FALSE | FALSE | FALSE | RUDI(/I/) |
| | **/T/R/** | TRUE | TRUE | FALSE | TRUE | 0000 1110 |
| **FEC parity** | **/D/D/** | TRUE | TRUE | FALSE | TRUE | 0000 1110 |
| **Special parity end** | **/ T/R/** | TRUE | TRUE | FALSE | TRUE | 0000 1110 |
| | **/K28.5/D21.2/** | FALSE | FALSE | FALSE | FALSE | RUDI(/I/) |
| | **/ T/R/** | TRUE | TRUE | FALSE | TRUE | 0000 1110 |
| **IDLEs** | **/IDLE/** | | FALSE | FALSE | FALSE | |

# PCS signaling for FEC device with FEC coded data

| Comments | 10B stream | Carrier Detect | Receiving | RX_DV | RX_ER | RXD<7:0> |
|---|---|---|---|---|---|---|
| **IDLEs** | **/IDLE/** | | FALSE | FALSE | FALSE | RUDI(/I/) |
| **Special Packet start** | **/R/R/K28.5/D21.2/S/** | TRUE | TRUE | TRUE | FALSE | 0101 0101 |
| **Data** | **/D/D/** | (All error states as before) | | | FALSE | DECODE[/x/] |
| **Special Packet end** | **/T/R/K28.5/D21.2/T/R/** | | TRUE | TRUE | FALSE | RUDI(/I/) |
| **FEC parity** | **/D/D/** | TRUE | TRUE | TRUE | FALSE | DECODE[/x/] |
| **Special parity end** | **/T/R/K28.5/D21.2/T/R/** | | FALSE | FALSE | FALSE | RUDI(/I/) |
| **IDLEs** | **/IDLE/** | | FALSE | FALSE | FALSE | RUDI(/I/) |

# Rx. State-Machine – FEC Sublayer



# Rx. State-Machine – FEC Sublayer