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Scrambled Encoding For 10 GigE

IEEE 802.3 Higher Speed Study Group June 1-3, 1999

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Agenda

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- **Achieving Encode Efficiency**
- **A Scrambler Physical Code Sublayer (PCS)**
- **Summary**

Scrambling = High Efficiency

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- 25% more efficient than 8b10b block code
- Increases reach up to 1.5X
- Reduced power consumption
- Simple to implement
- Reduced emission energy
- WAN compatible

Scrambled = Low Overhead

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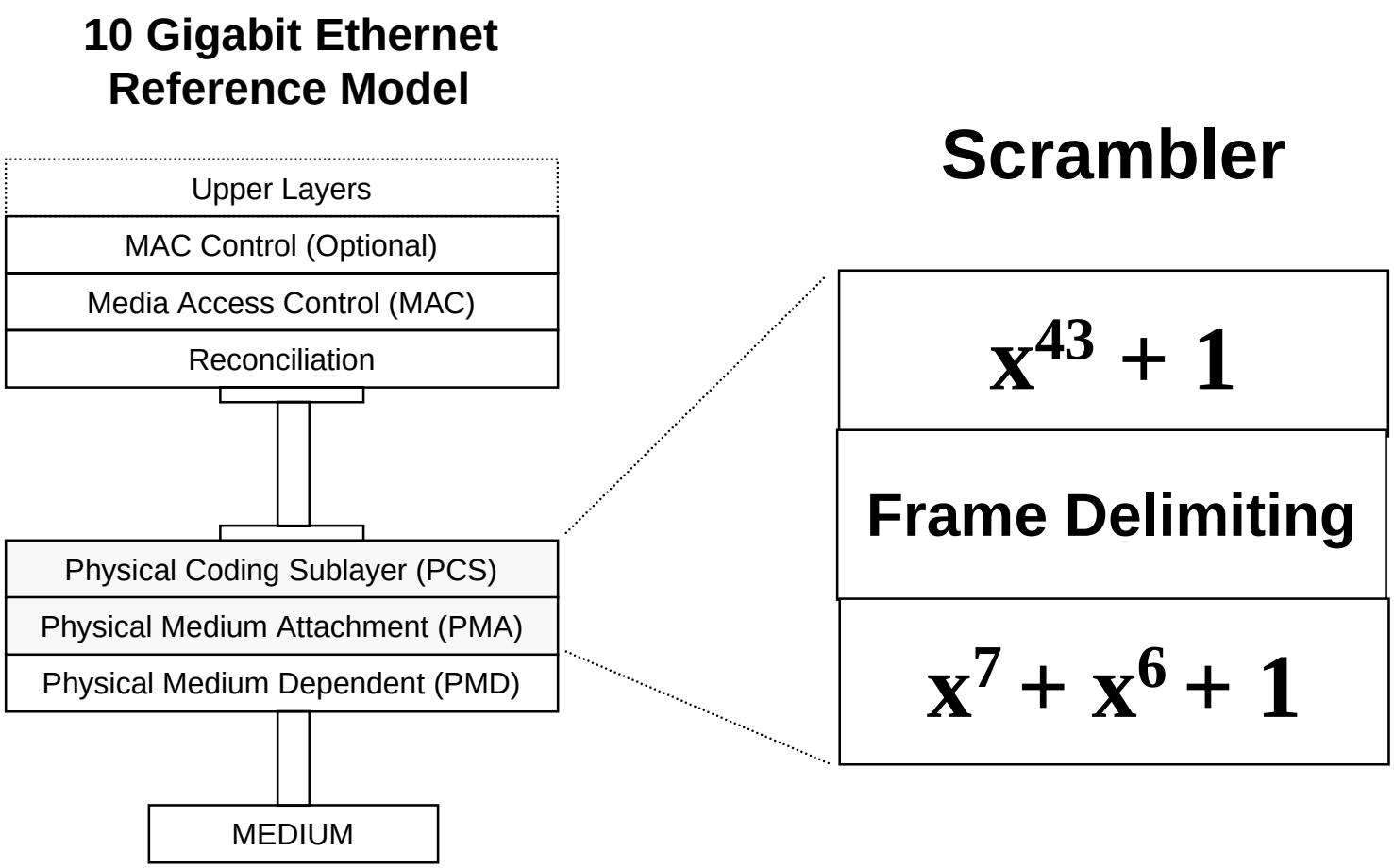
	OVERHEAD
• Scrambled	4% + Preamble + IFG
• POS	4% + Byte Stuffing + PPP Headers
• ATM	4% + 9.43% + Cell Packing Loss
• 8/10	25% + Preamble + IFG
• 4/5	25% + Preamble + IFG
• Manchester	100% + Preamble + IFG

A Scrambler PCS Layer



Scrambler Proposal

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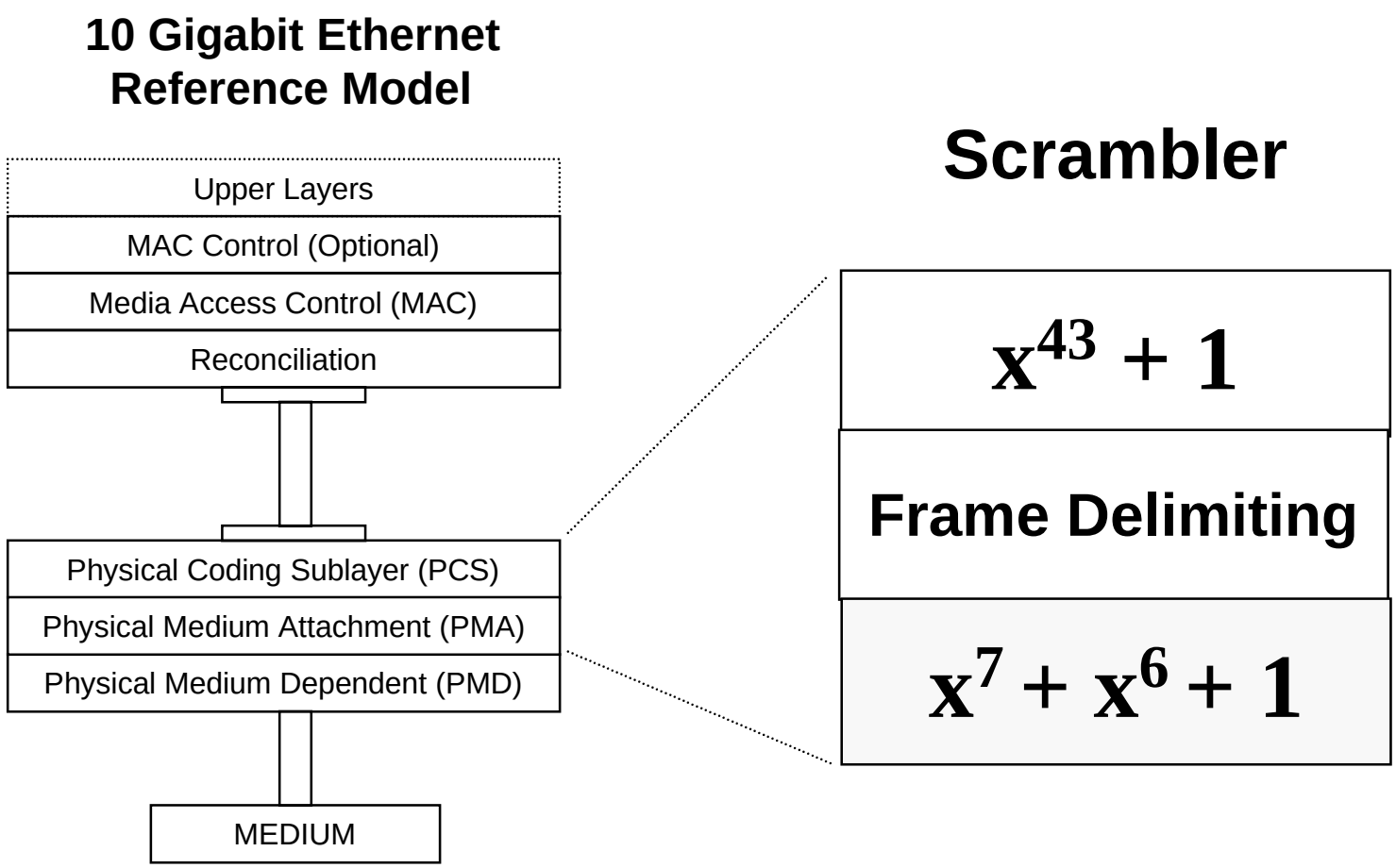
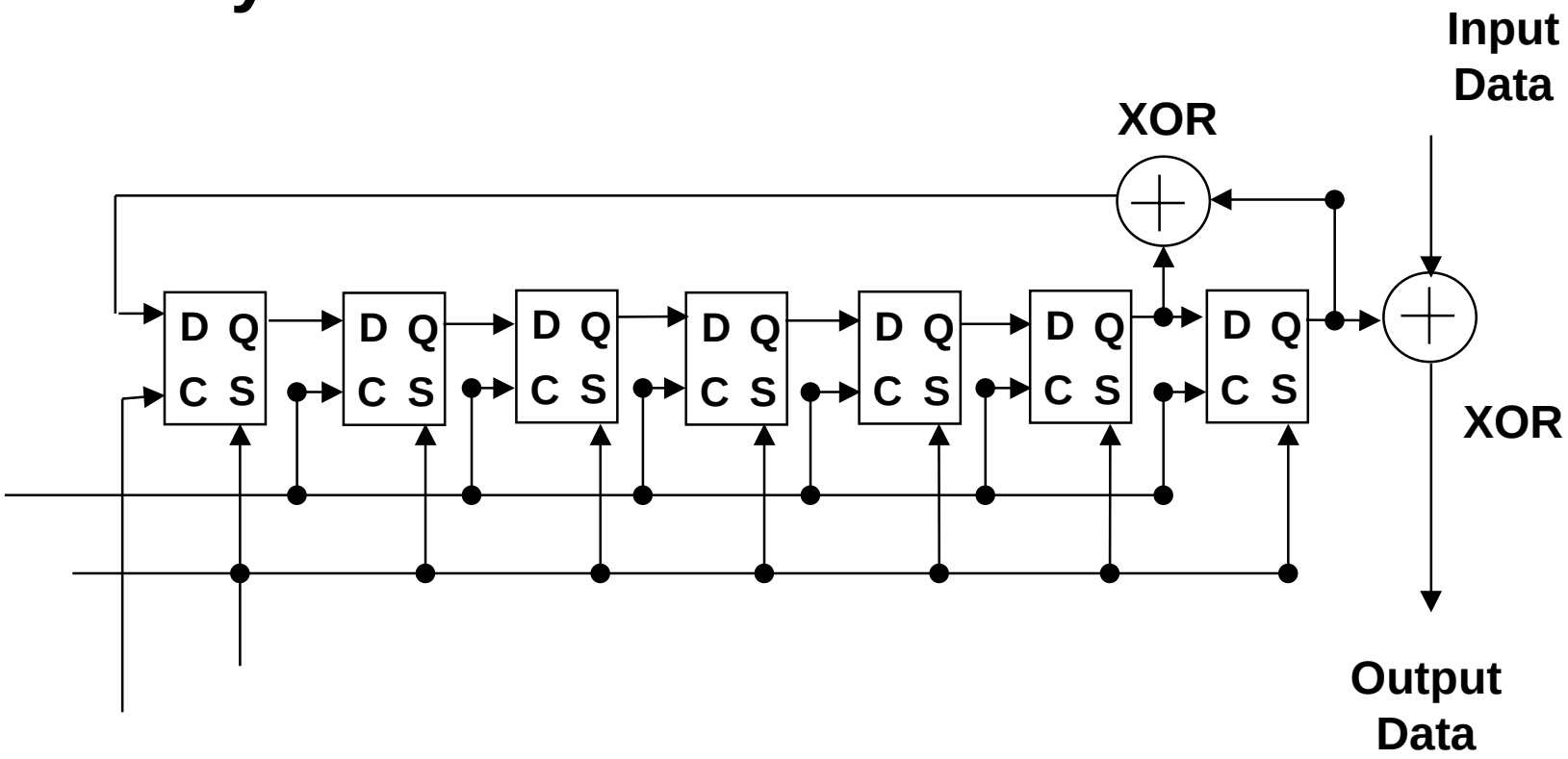
- **Use a 2 polynomial scrambler system**
  - **$x^7 + x^6 + 1$** over all data
  - **$x^{43} + 1$** from MAC DA through MAC CRC
- **Perform frame delimiting using <length> <type><hcs> pointer chains**
- **$x^7 + x^6 + 1$ is periodically resynchronized**
- **$x^{43} + 1$ self synchronizing**

$x^7 + x^6 + 1$ Layer


10 Gigabit Ethernet
Reference Model
Upper Layers
MAC Control (Optional)
Media Access Control (MAC)
Reconciliation
Physical Coding Sublayer (PCS)
Physical Medium Attachment (PMA)
Physical Medium Dependent (PMD)
MEDIUM
Scrambler
$x^{43} + 1$
Frame Delimiting
$x^7 + x^6 + 1$

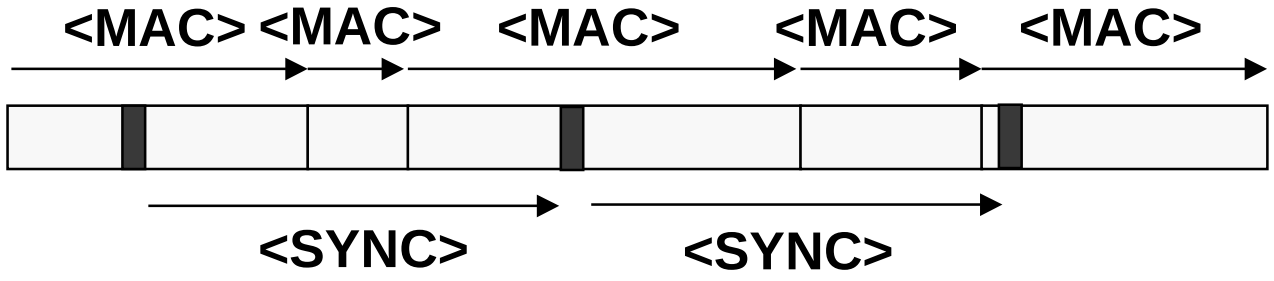
Polynomial $x^7 + x^6 + 1$

- **Produces High Randomization**
- **Easy to Attack**

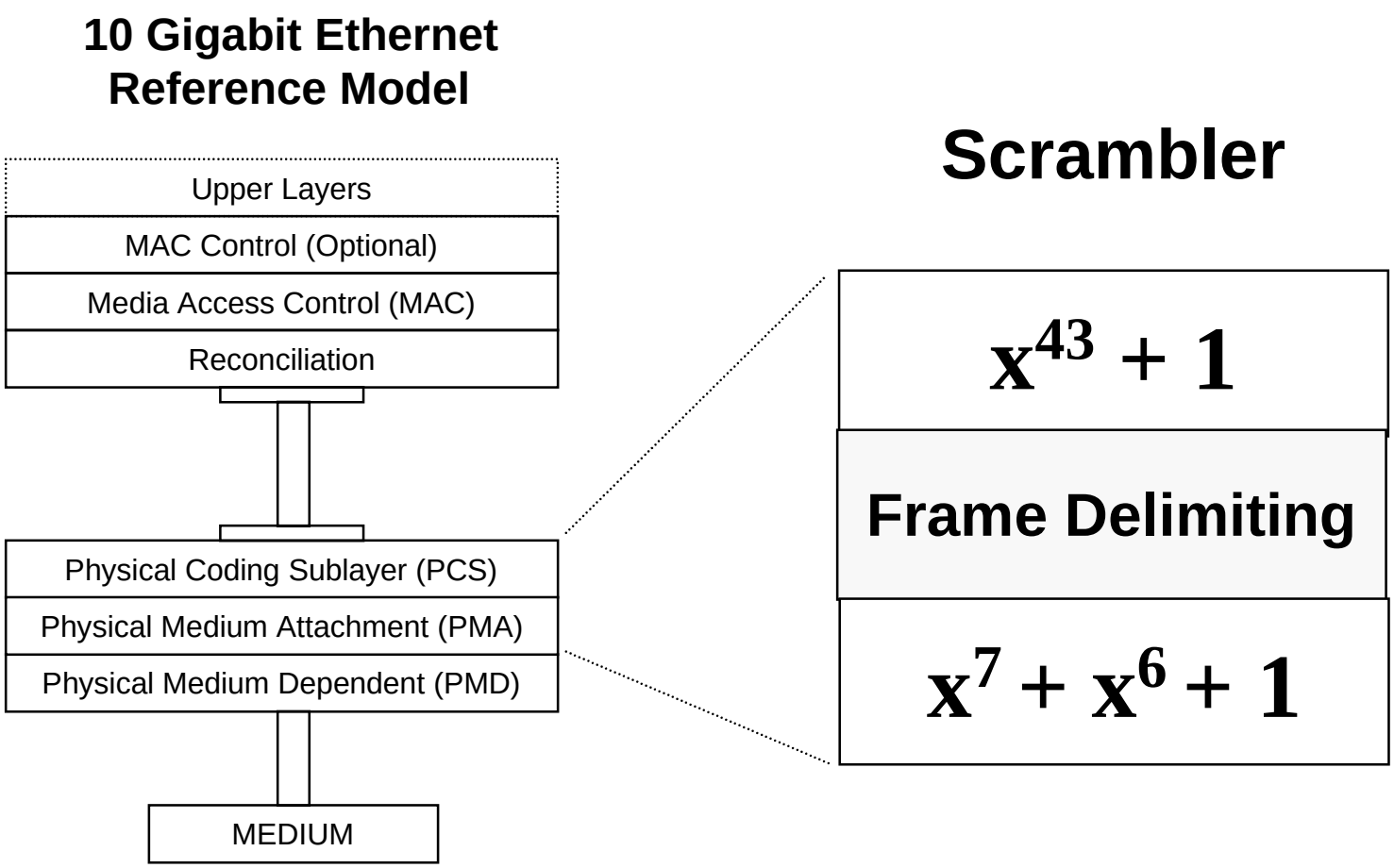


Synchronizing $x^7 + x^6 + 1$

- **Scrambler synchronization is signaled from the transmitter PHY to the receiver PHY by periodically sending an unscrambled synchronization string <SYNC>**
- **Each synchronization string is a fixed distance in transmitter bytes from the previous string**
- **Receivers synchronize the $x^7 + x^6 + 1$ scrambler by presetting to 1111111 at the end of the <SYNC> sequence**
- **The receiver removes the <SYNC> sequence from the data stream before passing data up to the $x^{43} + 1$ scrambler**

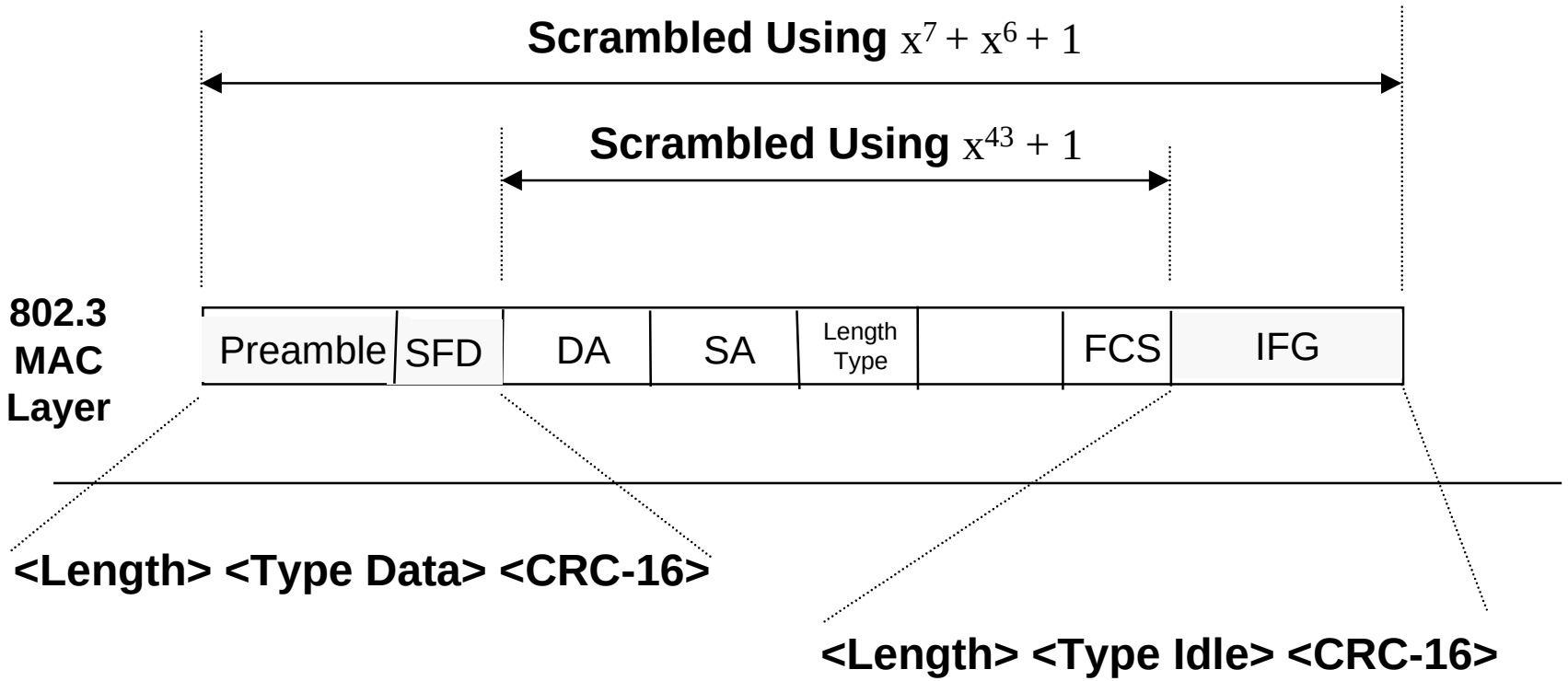


Frame Delimiting Layer



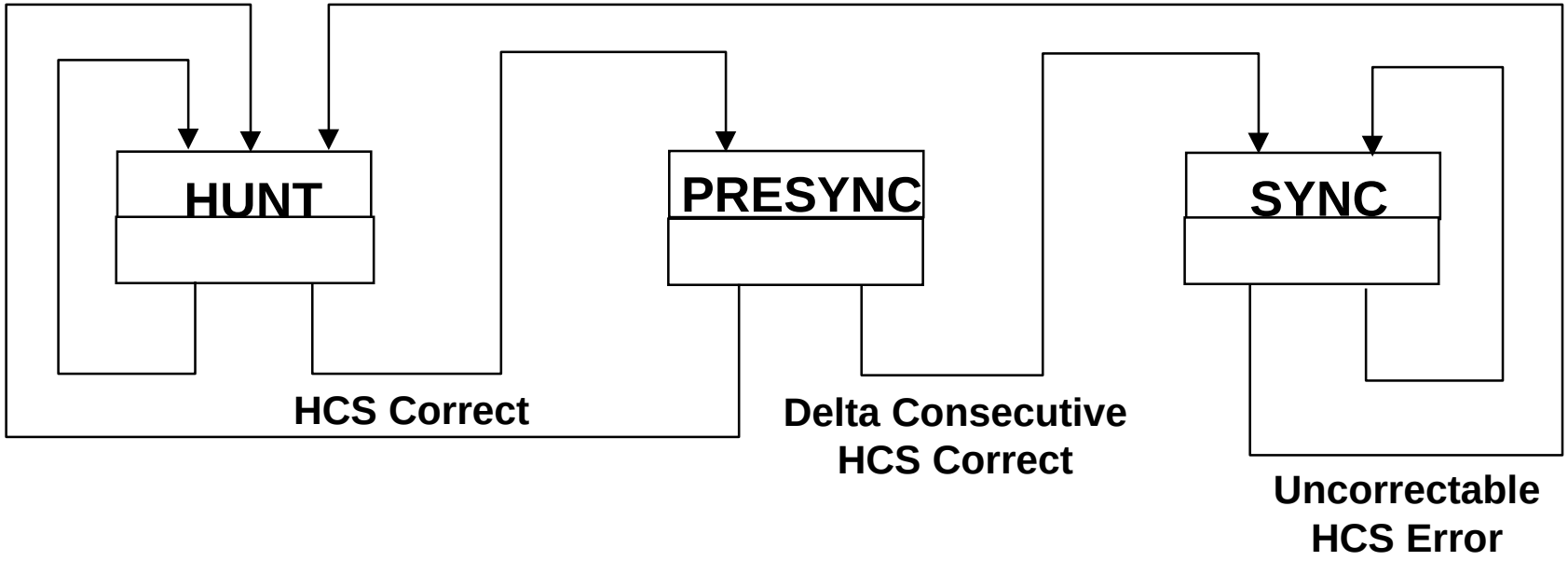
MAC Frame Delimiting

- **Preamble and IFG replaced with <Length> <Type><CRC>**
- **<Type> indicates data, idle, or management**

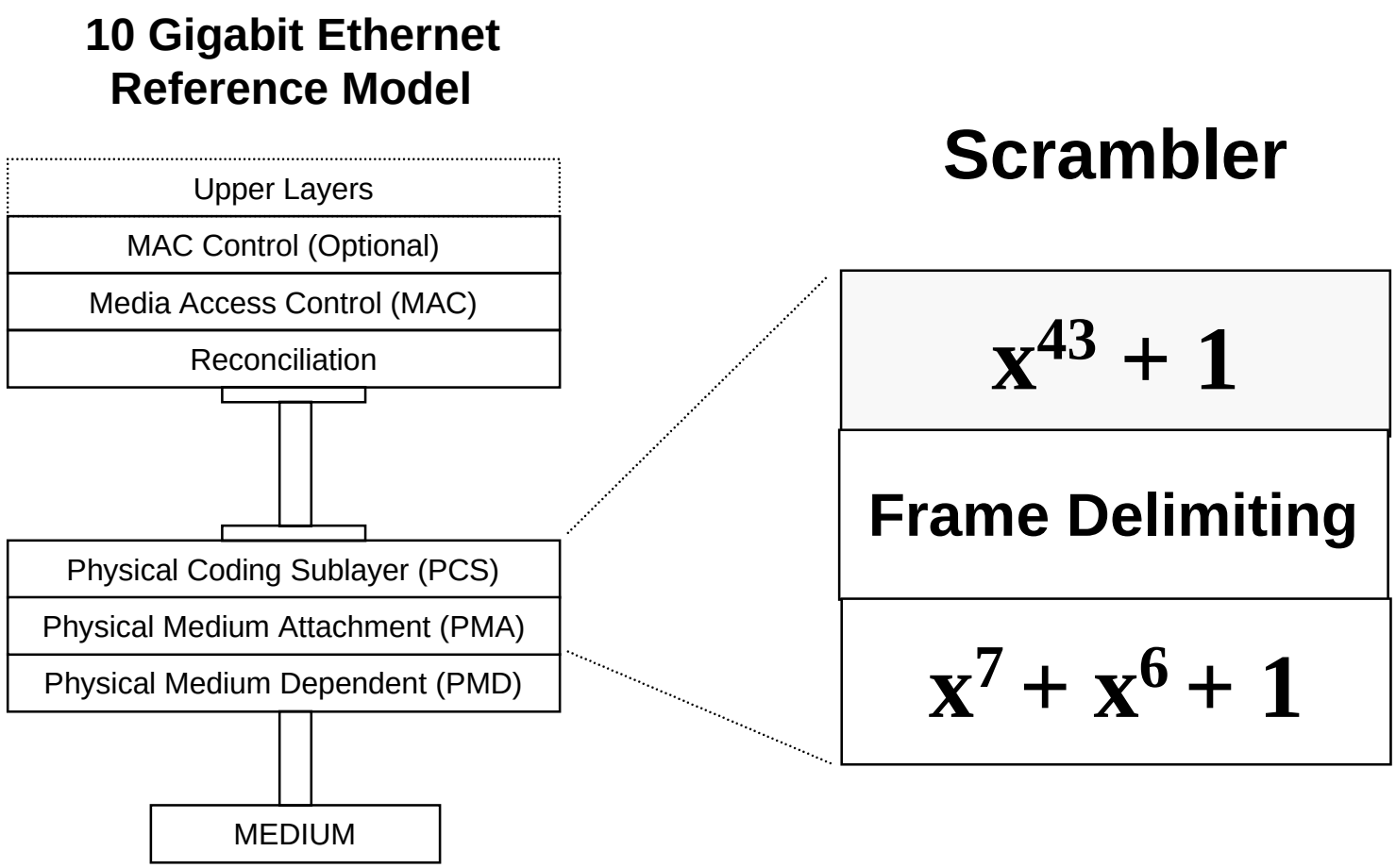


Frame Synchronization

- **Frame Synchronization occurs after synchronizing** $x^7 + x^6 + 1$
- **Frame SYNC based on matching a 16 bit CRC repeatedly**
- **With IFG frame SYNC time can be as short as 1 frame time**



$x^{43} + 1$ Layer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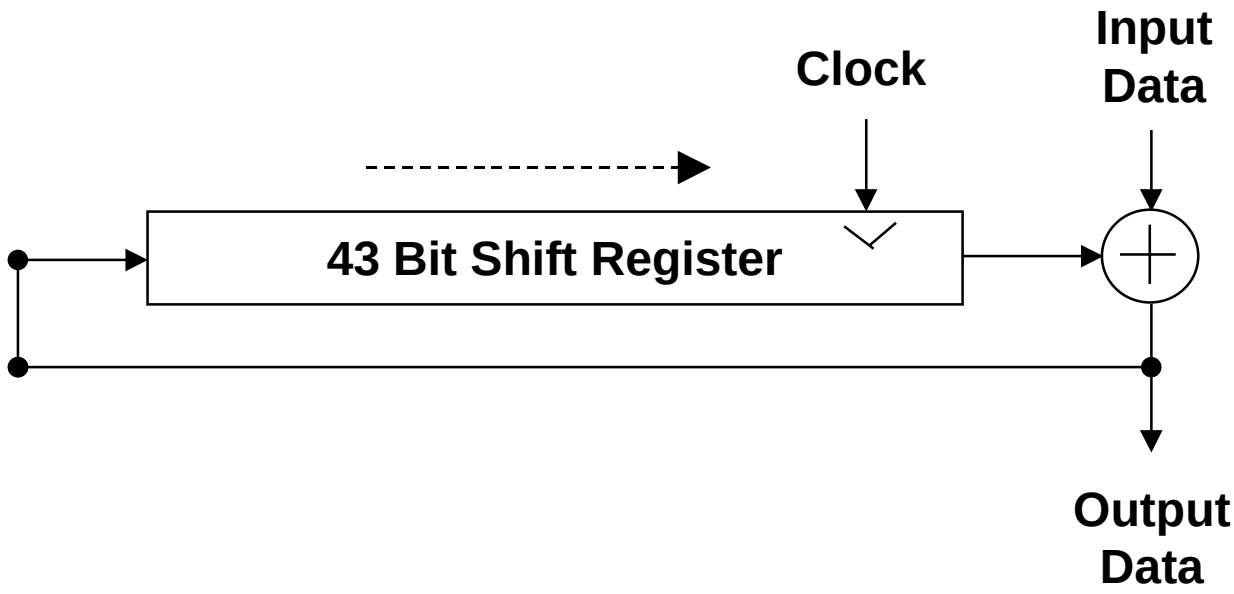
Scrambler
$x^{43} + 1$
Frame Delimiting
$x^{7} + x^{6} + 1$

Polynomial $x^{43} + 1$

- **Hard to Attack**
- **Poor Randomization**



Synchronizing $x^{43} + 1$

- **Self synchronizing**
- **Synchronizes on 43 bits of data**
- **Synchronization must following** $x^7 + x^6 + 1$

Creating Control Frames

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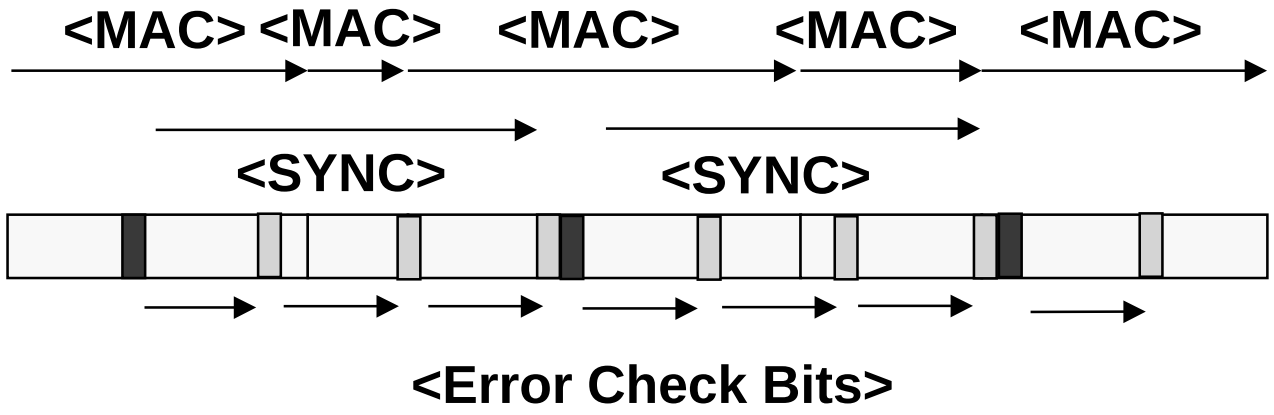
- Use <Type> filed to create PHY control frames
- Idle frames used for IFG are a special control frame
- Control frames may be placed between idle and data frames
- Control frames may be used in place of special character codes for management

Link Error Rate Monitoring

- **Error check located at fixed offset from scrambler synchronization marks**
- **Error check patterns occur in the middle of MAC frames**
- **Error check cover all data octets**



Preliminary Analysis Results

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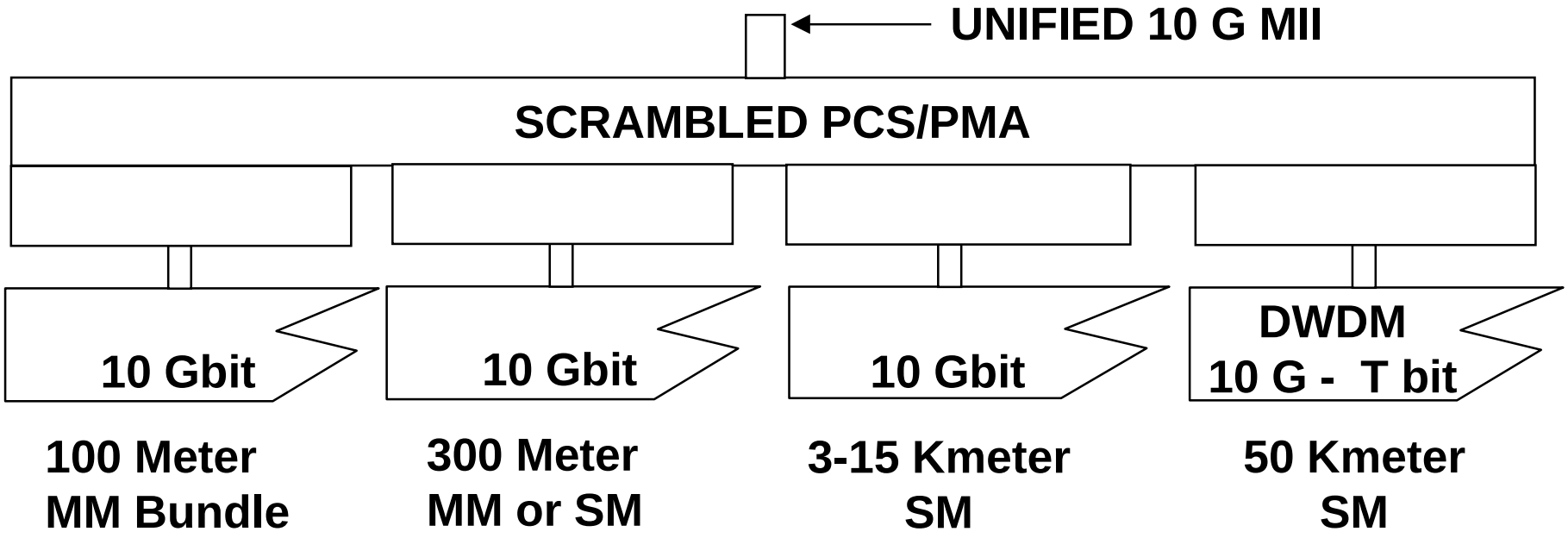
- **No MAC frame data pattern exists which will break the scrambler since the period of $x^{43} + 1$ is much longer than a MAC frame**
- **The average time to generate a string of 72 zeros is over 10,000 years**
- **Error duplication from the $x^{43} + 1$ scrambler will not weaken CRC-32 error detection**

Scrambler BER Below 10^{-12}

- **Without Forward Error Correction standards for OC-48 and OC-192 specify an error rate of 10^{-12}**
- **For reference see BCR GR-1377-CORE Section 4.2.1, page 4-3**
- **These specifications are absolute worst case at the end of life**

Putting A System Together

- **Scrambled encode could be used for all fiber media**
- **4 Fiber Lengths**
  - 100 Meter
  - 300 Meter
  - 3-15 Kmeter
  - 50 Kmeter



Unifying Ethernet and WAN

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- 9.95328 is the baud rate of SDH-64/OC-192
- 9.620928 is the bit rate of OC-192c
- 9.584640 is the bit rate of SDH-64c
- Ethernet at 9.584640 with scrambled encode can be transported over a SDH-64/OC-192 TDM channel
- Ethernet with scrambled encode can be carried directly over a single wavelength of a DWDM network in both metro and long haul

Dark Fiber Applications

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- Provides increased reach
- Provides reduced power
- Provides lower emission
- Allows seamless connection between dark fiber and DWDM

Summary

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- **Scrambled encoding allows a single scheme for both LAN and WAN applications**
- **Scrambled encoding provides higher code efficiency than 8/10 with increased reach, lower cost optic components, lower power, lower emissions**
- **Scrambled encoding works well over a variety of PMA layers**
- **Scrambled encoding allows easy integration with WAN networks**
  - Improved reach
  - Compatible with DWDM regenerator networks
  - Can carry over SONET TDM