1000BASE-T
Duffer's Guide to Basics and Startup

Steve Pryor
Manager, Training Development Services
Compaq Computer Corporation
1000BASE-T Basics

- 1000 Mb/s using 4 pairs of Cat 5 UTP Cable
- Distance: 100 Meters
- Half or Full Duplex
- TX and RCV simultaneously on all 4 pairs
Data Flow

GMII 8 bits \(\Rightarrow\) Side-Stream Scrambler + Trellis Encoder 9 bits \(\Rightarrow\) Lookup Table

1 Quinary Quartet (8B/1Q4) \(\leftrightarrow\) 1 of 5 Voltage Levels per Cat. 5 Pair*

01001010 \(\leftrightarrow\) 101011010 \(\leftrightarrow\) +1, 0, -2, -1 \(\leftrightarrow\) +0.5, 0.0, -1.0, -1.0

* Actually 17 voltage levels to reduce emissions by shaping the output
The requirements
(What 1000BASE-T has to do)

• Maintain timing synchronization between slave and master
• Successfully receive signals on four pair at 125MBAUD
• Successfully perform the following within timing constraints (8ns):
  – Remove ISI through equalization
  – Remove ECHO (from near-end XMT and its channel reflection)
  – Remove NEXT (from each of other three pairs)
  – Remove FEXT (from each of other three pairs)
• Recover the correct code group from the 4D-PAM5 signals recovered
  – uses a Viterbi decoder
• Descramble the recovered code group
Gigabit Receiver With FEC

PER CHANNEL
( Channel 1 shown below )

Remove Precursor ISI

Input Samples to Viterbi

From Other Channels

Provides 6dB coding gain

Remove Post Cursor ISI

Decision Feedback Equalizers

TX output channel 1

TX output channel 2,3,4

TX output channel 2,3,4

Receive Signal

AFE

A/D Conv

Feed Forward Equalization

Viterbi Decoder

Quinary Quartet

Recovered Clock

Conv

8

DFE #1

DFE #N

Echo Canceller

NEXT Cancellers(3)

FEXT Cancellers(3)
Linear Equalizer with LMS Update

The equalizers, NEXT cancellers and echo cancellers in a 1000Base- T transceiver are all variations of this filter structure.
Why Start-up

• Slave must acquire clock so it can synchronize its operations to the Master’s clock. This relationship must be maintained on an on-going basis.

• Both Master and Slave must “train” all 36 adaptive equalizers so they “understand” the noise on the link (and elsewhere) and are prepared to filter it.

• Train equalizers (DFE, FFE)

• Train noise cancellers (Echo, NEXT, FEXT)
Problems at start-up

• Signal analysis complexity in the receiver at start-up
  • ISI
  • Return loss (from impedance mis-matches in the channel)
  • Echo (from this channel’s TX)
  • NEXT (from 3 pair’s TX)
  • FEXT (from 3 pair’s far-end TX)
  • External noise
• Easier to train equalizers in the absence of echo
The “Smart Blind” Solution

• Maintains the implementation simplicity of blind start-up.

• Slave delays transmitting up to 350 ms (should be less than 10 ms) to provide the opportunity for equalizer training without echo before blind start-up activities begin.
“Classic Blind” Start-up

\[ \text{link\_control} = \text{DISABLE} + \]
\[ \text{pma\_reset} = \text{ON} \]

**DISABLE 1000BASE-T**

**TRANSMITTER**

\[ \text{link\_control} = \text{ENABLE} \]

**TRAINING**

Start minwait\_timer
Start maxwait\_timer
\[ \text{tx\_mode} \Leftarrow \text{SEND\_I} \]

minwait\_timer\_done *  
loc\_rcvr\_status = OK *  
rem\_rcvr\_status = OK

SEND IDLE OR DATA

Stop maxwait\_timer
Start minwait\_timer
\[ \text{tx\_mode} \Leftarrow \text{SEND\_N} \]

minwait\_timer\_done *
loc\_rcvr\_status = OK *
rem\_rcvr\_status = OK

SEND IDLE

Stop maxwait\_timer
Start minwait\_timer
\[ \text{tx\_mode} \Leftarrow \text{SEND\_I} \]

minwait\_timer\_done *
loc\_rcvr\_status = OK *
rem\_rcvr\_status = NOT_OK

SEND IDLE

Stop maxwait\_timer
Start minwait\_timer
\[ \text{tx\_mode} \Leftarrow \text{SEND\_I} \]

minwait\_timer\_done *
loc\_rcvr\_status = NOT_OK

minwait\_timer\_done *
loc\_rcvr\_status = NOT_OK
“Smart Blind” Start-up

1. link_control = DISABLE + pma_reset = ON
2. DISABLE 1000BASE-T TRANSMITTER
3. link_control = ENABLE
4. SLAVE DFE CONVERGENCE
5. Start maxwait_timer
6. tx_mode = SEND_Z
7. config = MASTER +
8. loc_rcvr_status = SCR_OK
9. TRAINING
10. Start minwait_timer
11. tx_mode = SEND_I
12. SEND IDLE OR DATA
13. Stop maxwait_timer
14. Start minwait_timer
15. tx_mode = SEND_N
16. minwait_timer_done *
17. loc_rcvr_status = OK *
18. rem_rcvr_status = OK
19. SEND IDLE
20. Stop maxwait_timer
21. Start minwait_timer
22. tx_mode = SEND_I
23. minwait_timer_done *
24. loc_rcvr_status = OK *
25. rem_rcvr_status = OK
26. SEND IDLE OR DATA
27. Stop maxwait_timer
28. Start minwait_timer
29. tx_mode = SEND_N
30. minwait_timer_done *
31. loc_rcvr_status = NOT_OK
32. Disable 1000BASE-T
33. pma_reset = ON
34. link_control = DISABLE +
35. link_control = ENABLE
36. Phase 1
37. Phase 2
“Smart” Blind Start-up

Master

Phase 1

E

Phase 2

E, D, P

DONE

Slave

D, T

E

DONE

E = Echo/NEXT Canceller Convergence
T = Timing Convergence
P = Adjust Phase
D = Equalizer Convergence