Modified Clause 73 Auto-Negotiation Detailed Proposal

IEEE 802.3bp - Plenary Meeting - March 2014

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Agenda

- Brief Recap on Theory of Operation
- State Machine Changes
  - 3 Existing State Machine + New one
- Timer and Variable Changes
- Possible Optimizations
- Electricals
Half Duplex Differential Manchester Encoded Auto-Negotiation

- Use modified 802.3ap Clause 73 Auto-Negotiation for Backplane

- Differential Manchester Encoding instead of linkpulses
  - But not continuously transmitted (half duplex)
  - DC balanced, Partially Randomized
Auto-Negotiation DME Page

- DME Page consists of 48 data bits + 1 random bit + delimiters

- What’s New:
  - Not continuously transmitted – DME pages separated by quiet time
  - Extra delimiter added at end of DME page to delineate from quite time

Proposed values

<table>
<thead>
<tr>
<th>#</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Transmit position spacing (period)</td>
<td>39</td>
<td>40</td>
<td>41</td>
<td>ns</td>
</tr>
<tr>
<td>T2</td>
<td>Clock transition to clock transition</td>
<td>76</td>
<td>80</td>
<td>84</td>
<td>ns</td>
</tr>
<tr>
<td>T3</td>
<td>Clock transition to data transition (data = 1)</td>
<td>36</td>
<td>40</td>
<td>44</td>
<td>ns</td>
</tr>
<tr>
<td>T4a</td>
<td>+1 to -1 or -1 to +1 transitions in a DME page</td>
<td>52</td>
<td>-</td>
<td>101</td>
<td>-</td>
</tr>
<tr>
<td>T4b</td>
<td>0 to +/-1 or +/-1 to 0 transitions in a DME page</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>T5</td>
<td>DME page width</td>
<td>4446</td>
<td>4560</td>
<td>4674</td>
<td>ns</td>
</tr>
<tr>
<td>T6</td>
<td>DME Manchester violation delimiter width</td>
<td>156</td>
<td>160</td>
<td>164</td>
<td>ns</td>
</tr>
</tbody>
</table>
Auto-Negotiation DME Page

- The 49 data bit is a random bit is generated according to Clause 73: $X^7 + X^3 + 1$ or $X^7 + X^6 + 1$

- The generator is advanced once per DME page

- The DME page is polarity insensitive and the random bit has the effect of inverting the DME page polarity.

- The polarity of the next DME page shall be such that Start delimiter is the same polarity as the End delimiter of the current DME page
Half Duplex Operation

- PHYs take turns sending and receiving DME pages
- Blind period to avoid seeing echo from self
- After page received Wait (Silent) period needed since link partner may be in Blind period
- Wait period slightly longer than Blind Period
- Examples below with max cable length and zero cable length
Signal Separation on Startup

- Both transmit overlap and no page seen – receive times out
  - Timeout value should be longer than DME_page_width + Wait (Silent) period

- PHYs will randomly decide whether to delay zero or more additional Wait period while still keeping receiver on
  - Assuming 16 possible delay settings 1 in 1 trillion chance of going beyond 10 tries

- PHY that waits more should receive page and should sync up system and no more random waits are needed

- At startup PHY should always listen for at least one Wait period prior to transmitting first page
Clause 73 Arbitration State Machine Changes

- Remove states related to parallel detection since there is no legacy PHY without Auto-Negotiation to support
- SCAN_FOR_CARRIER does not apply since there is no legacy PHY generating signals
- Otherwise no changes
Clause 73 Arbitration State Machine Changes

- **PARALLEL DETECTION FAULT**
  - `mr_parallel_detection_fault = true`
  - `link_control_[a] = DISABLE`
  - `single_link_ready=false`

- **LINK STATUS CHECK**
  - Start autoneg_wait_timer
  - transmit_disable = true
  - `link_status_\[KX\]=OK`
  - `link_status_\[KX4\]=OK`
  - `single_link_ready=true` +
  - `autoneg_wait_timer_done`

- **States removed since no parallel detect is supported or needed**

- **ABILITY DETECT**
  - `transmit_ability = true`
  - `mr_lp_autoneg_able = false`
  - `link_control_[PD] = SCAN_FOR_CARRIER`
  - `toggle_tx = mr_adv_ability[12]`
  - `ability_match = false`
  - `acknowledge_match = false`

- **ABILITY DETECT** (IF `base_page=true`) THEN
  - `tx_link_code_word[10:6] = rx_nonce[4:0]`
  - `transmit_ack = true`
  - `mr_lp_autoneg_able = true`
  - `link_control_[all] = DISABLE`

- **BREAK_LINK_TIMER**
  - Start break_link_timer
  - `link_control_[all] = DISABLE`

- **TRANSMIT DISABLE**
  - `transmit_disable = true`
  - `mr_page_rx = false`
  - `mr_autoneg_complete = false`
  - `mr_next_page_loaded = false`

- **COMPLETE ACKNOWLEDGE**
  - `complete_ack = true`
  - `transmit_ability = true`
  - `transmit_ack = true`
  - `toggle_rx = rx_link_code_word[12]`
  - `toggle_tx = toggle_tx`
  - `mr_page_rx = true`
  - `np_rx = rx_link_code_word[NP]`
  - `mr_lp_adv_ability = rx_link_code_word`

- **COMPLETE ACKNOWLEDGE**
  - `ack_finished=true` +
  - `mr_next_page_loaded=true`
  - `((tx_link_code_word[NP]=1) + (np_rx=0))`

- **NEXT PAGE WAIT**
  - `transmit_ability = true`
  - `mr_page_rx = false`
  - `base_page = false`
  - `tx_link_code_word[12] = toggle_tx`
  - `ack_finished = false`
  - `mr_next_page_loaded = false`

- **AN GOOD CHECK**
  - `link_control_[notHCD] = DISABLE`
  - `link_control_[HCD] = ENABLE`
  - `an_link_good = true`
  - `start_link_fail_inhibit_timer`

- **AN GOOD CHECK**
  - `((link_status_[HCD]=FAIL + link_status_[HCD]=OK) + link_fail_inhibit_timer_done) + incompatible_link = true`

- **ACKNOWLEDGE DETECT**
  - `ability_match=true` +
  - `nonce_match=true`
  - `((toggle_rx ^ ability_match_word[12])=1)`

- **ACKNOWLEDGE DETECT**
  - `ack_finished=true` +
  - `tx_link_code_word[NP]=0`
  - `np_rx=0`

- **NEXT PAGE WAIT**
  - `transmit_ability = true`
  - `mr_page_rx = false`
  - `base_page = false`
  - `tx_link_code_word[12] = toggle_tx`
  - `ack_finished = false`
  - `mr_next_page_loaded = false`

- **NEXT PAGE WAIT**
  - `an_receive_idle=true`
### Clause 73 Transmit State Machine Changes

- **WAIT1 and WAIT2 states** pauses the next DME page transmission until Half-Duplex state machine gives go ahead to continue via transmit_DME_wait

- **transmit_DME_done** lets the Half-Duplex state machine know if a DME page is being transmitted or not

- **TRANSMIT DELIMITER TAIL** state adds the end delimiter to the DME page
DELIMITER WAIT state processes delimiter at the end of the DME page

receive_DME_active lets the Half-Duplex state machine know if a DME page is being received or not

The Half-Duplex state machine blinds the Receive State Machine with receive_blind
Half-Duplex State Machine

- State Machine cycles through Blind, Receive, Silent (Wait), and Transmit
- Interacts with Transmit and Receive SM via 4 variables
  - receive_blind
  - receive_DME_active
  - transmit_DME_wait
  - transmit_DME_done
- RECEIVE WAIT to TRANSMIT ACTIVE has random backoff component if no DME page received
- RECEIVE ACTIVE to TRANSMIT ACTIVE to recover if delimiter at end of page is mistaken for delimiter at start of page
# Timers – Proposed Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>autoneg_wait_timer</td>
<td></td>
<td>deleted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>break_link_timer</td>
<td></td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>clock_detect_min_timer</td>
<td>68</td>
<td>76</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>clock_detect_max_timer</td>
<td>84</td>
<td>92</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>data_detect_min_timer</td>
<td>28</td>
<td>36</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>data_detect_max_timer</td>
<td>44</td>
<td>52</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>interval_timer</td>
<td>39</td>
<td>40</td>
<td>41</td>
<td>ns</td>
</tr>
<tr>
<td>link_fail_inhibit_timer</td>
<td></td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>page_test_min_timer</td>
<td>4366</td>
<td>4406</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>page_test_max_timer</td>
<td>4714</td>
<td>4754</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>blind_timer</td>
<td>2000</td>
<td>2040</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>silent_timer</td>
<td>2120</td>
<td>2200</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>receive_DME_wait_time</td>
<td>6794</td>
<td>6874</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>backoff_time</td>
<td>2120</td>
<td>2200</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>receive_DME_timer</td>
<td></td>
<td>receive_DME_wait_time + random(0 to 15) x backoff_time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- New timers in red
Timer Notes

- `autoneg_wait_timer`
  - Deleted since no parallel detect

- `break_link_timer` – Recommend 100us
  - Need further study if PCS, PMA can detect link drop this quickly

- `linkfail_inhibit_timer`
  - Need further study to determine how fast PCS, PMA can link up
  - Provision should be made to add more margin for future PHYs

- `blind_timer`
  - Amount of time needed for worst case round trip echo propagation
  - 2000 ns is good for 200 meter – more than sufficient for future proofing
  - Note that echos may propagate for more than 1 round trip

- `silent_timer`
  - Wait time should be slightly longer than blind_timer to guarantee that link partner is not blinded when DUT starts transmitting
Timer Notes

- **receive_DME_wait_time**
  - Longer than sum of DME_page_width + silent_timer
  - Allows sufficient time to see link partner’s DME page

- **backoff_time**
  - Same as silent_time

- **interval_timer**
  - N x 25MHz friendly
# New Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>transmit_DME_wait</td>
<td>true = pause DME page transmission</td>
</tr>
<tr>
<td></td>
<td>false = continue DME page transmission</td>
</tr>
<tr>
<td>receive_blind</td>
<td>true = ignore received DME transitions</td>
</tr>
<tr>
<td></td>
<td>false = accept received DME transitions</td>
</tr>
<tr>
<td>receive_DME_timer_limit</td>
<td>Timer duration for receive_DME_timer</td>
</tr>
<tr>
<td>receive_DME_active</td>
<td>true = DME page reception in progress</td>
</tr>
<tr>
<td></td>
<td>false = DME page reception completed</td>
</tr>
<tr>
<td>transmit_DME_done</td>
<td>true = DME page transmission completed</td>
</tr>
<tr>
<td></td>
<td>false = DME page transmission in progress</td>
</tr>
</tbody>
</table>

- **Rnd()**
  - Random number generator outputting integer from 0 to 15 inclusive
**DME Page Formatting**

- S[4:0] and C[2:0] – Same as 802.3ap
  - S[4:0] set to 00001
  - C[2:0] used for pause

- E[4:0] and T[4:0] randomized – Same as 802.3ap
  - Also use this for Master/Slave Random Seed

- A[24:0] – Technology Ability Field
  - This task force and future task force to define

- F[1:0] – Propose change from FEC to Master/Slave
  - F[0] – Master Slave Config

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Master Slave Random Seed

- If both PHYs prefer to be master or both prefer to be slave the master / slave random seed kicks in

- If the randomly generated T[4:0] field of both PHYs the same the arbitration state machine forces restart (nonce_match)
  - Enhancement possible to guarantee nonce_match is always false

- Hence T[4:0] of both PHYs will never be the same upon successful exchange
  - PHY with higher T[4:0] value will be the master
Optional Enhancement for State Machine Optimization

- **remaining_ack_cnt**
  - Currently need to send 6 to 8 pages to complete exchange
  - Since half duplex operation forces both PHYs to be in sync we can set this to a lower number (recommend 3).

- **nonce_match**
  - Currently forces the state machine to recycle to TRANSMIT DISABLE state and wait another break_link_timer
  - Instead of waiting to see 3 link partner pages, change the transmitted T[4:0] on the fly while in the ABILITY MATCH state if the T[4:0] of the first page received matches.
  - Since the system is half-duplex, the link partner probably never received the DUT page and does not know the DUT’s T[4:0] value so changing on the fly does not hurt.
  - To prevent the new T[4:0] from being the same as the previous one, the proposal is to invert the previous T[0] and randomly generate a new T[4:1].
Electrical Interface

- **Use PAM3 Transmitter as is**
  - Electrical levels – TBD by task force
  - Rise and fall times – TBD by task force
  - DME – use PAM3 +1, -1 levels.
  - Quiet – either PAM3 0 level, or turn off

- **Two comparators needed for receiver**
  - One for PAM3 +1 detection, other for PAM3 -1 detection
  - Propose +50mV and -50mV thresholds
  - Need to bypass any on chip receive filtering
  - Comparators oversampled to reconstruct DME pulses
THANK YOU
Startup Times With Proposed Values

- **break_link_timer** – proposed 100 us

- **Startup retry resolution per attempt - worst case wait**
  - DME page + Blind period + receive time out + Wait period = 4.56 us + 2.0 us + 6.8 us + 15 * 2.16 us = 45.76 us

- **Once in sync each pair of pages takes**
  - 2 x (Wait period + DME page + propagation) = 2 x (2.16 us + 4.56 us + 1.0 us) = 15.44 us

- **Base page exchange**
  - 3 in Ability Detect, 3 in Acknowledge Detect, 6 in Complete Acknowledge = (3 + 3 + 6) * 15.44us = 185.28 us

- **DSP linkup time**
  - RTPGE Group to define based on modulation scheme and PCS

- **Total time not counting DSP link up time**
  - No retry – 100 us + 185.28 us < 300 us
  - 10 retry – 100 us + 10 x 45.76 us + 185.28 us < 750 us