Alignment Marker Lock State Machine for NRZ 100G-KR

IEEE P802.3bj, Minneapolis
May 2012

Zhongfeng Wang, Broadcom
Mark Gustlin, Xilinx

Supporters and Contributors

- Jeff Slavick, Avago Technology
- Roy Cideciyan IBM
- Hongtao Jiang Broadcom

Alignment Marker Block

- In 100G backplane and copper cable systems, after transcoding and data redistribution, we have groups of 5 consecutive Alignment Marker (AM) blocks on each physical lane. Each AM block has the format shown below.
- To check if a 64-b block is a AM block, we check M0, M1, M2, M4, M5, and M6 segments (totally 48 bits) for possible match.

	RS symbol index																													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
FECL<0>	AM0								AM4					AM8						AM12						AM16					
FECL<1>	AM1								AM5					AM9						AM13						AM17					
FECL<2>	AM2								AM6					AM10						AM14						AM18					
FECL<3>	AM3								AM7					AM11						AM15						AM19					

Alignment Marker Format							
M0	M1	M2	BIP3 CD3	M4	M5	M6	BIP7 CD7

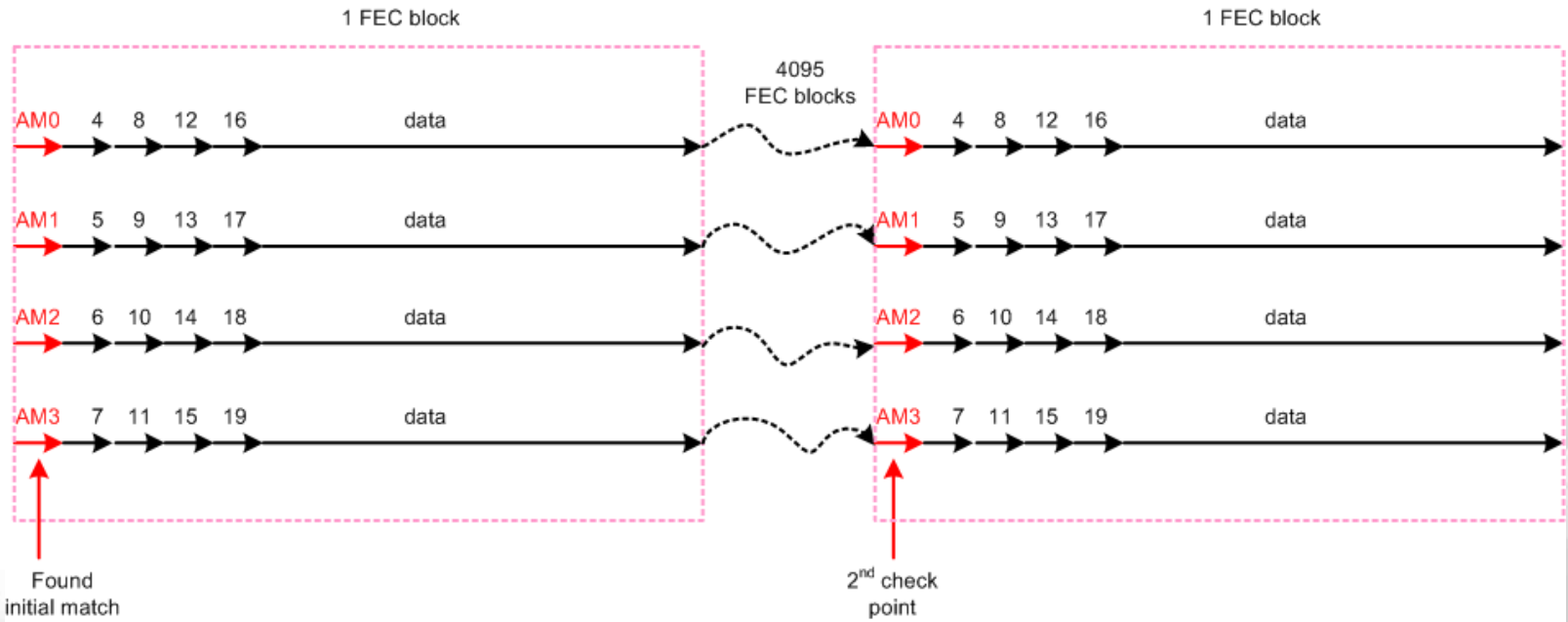
Overview of the Alignment Proposal

- On a per lane basis, lock to the first Alignment Marker (of the 5) by looking in parallel for a match (with an error tolerance) and once finding a match, look 4096 FEC blocks away for a 2nd match (for non EEE operation), if you find a match then you declare that lane in AM lock
- Once all 4 lanes are in AM lock, then you align the lanes and declare FEC lock. FEC lock is by definition known once you have AM lock and you deskew the 4 lanes.
- After FEC lock is declared, FEC unlock is declared once you see 3 FEC blocks in a row that have uncorrectable errors
  - Note that AM unlock is declared on all lanes once FEC unlock is declared

AM Block Matching Proposal

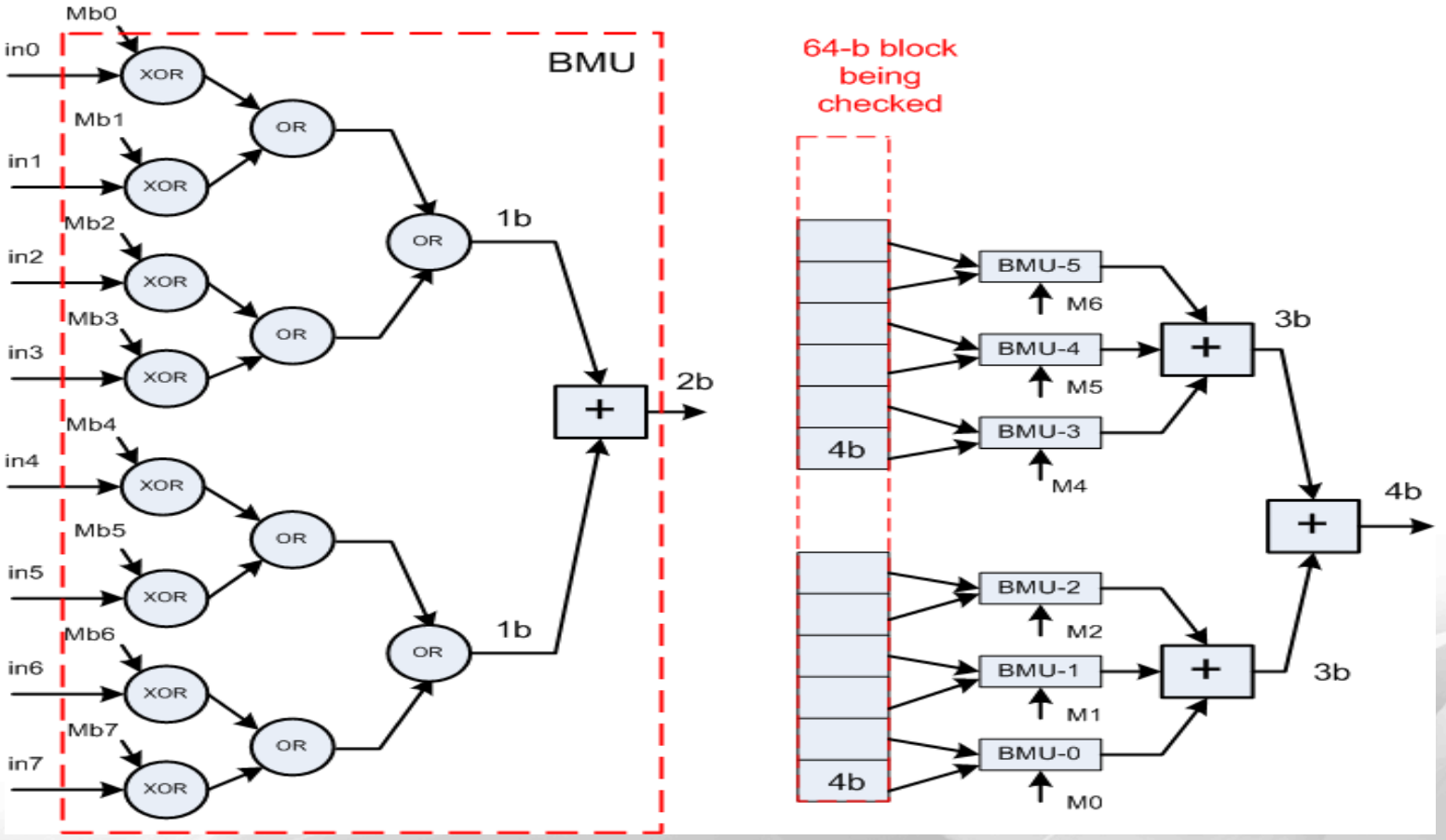
- From our analysis, block match with a tolerance of up to 3 4-b symbol errors achieves an optimal tradeoff between low false alignment probability and short worst-case lock time.

- To reduce computation complexity, we will only check block match for the first AM block in each group of 5 AM blocks.



Example Structure for Block Match

- If the total number of non-matched symbols is greater than 3, we will report “unmatch” for the block, where BMU stands for Byte Match Unit.



Lock Scheme and Analysis

- If two leading AM blocks in 2 consecutive groups are matched by definition, we will enter the “AM Lock” state for that physical lane.

- Mean time to AM lock:
  Tm=(1.5 + 1.5e-7) x delay between two AM groups

- False alignment probability:
  P(false align) ~1.0e-17 → mean time of 1.7e5 yrs.
  Impact if false alignment occurs: very quick unlock due to FEC uncorrectable errors

- Worst case lock time:
  P(not lock in 6 group delays) < 1.0e-21
  → mean time of 1.7e9 years
  The worst scenario: ---v---x---v---x---v---v

FEC Status for Unlock Detection

- Assume all 4 lanes are correctly aligned. Can we use the FEC lock status to declare unlock of the FEC and AMs?
- We need to be sure that the FEC decoding status will robustly indicate that we are out of lock quickly
  - At a BERout=1e-12, a FEC block is not decodable with probability of 2e-10 to 6e-10 depending on the assumed error propagation. Thus it is practically impossible to have 3 consecutive un-decodable FEC blocks when correctly aligned.
  - Therefore, it is robust to claim “unlock” when detecting 3 undecodable FEC blocks in a row

Use FEC Status for Unlock Detection (II)

- If there's any false alignment, .e.g., offset by 1 bit or 1 symbol for one lane, it will lead to 100+ symbol errors with high probability. In this case, a false decoding may happen. But the probability of false decoding will be about 1.6e-6. A worst case ($p < 6.5e-24$) is given as follows:

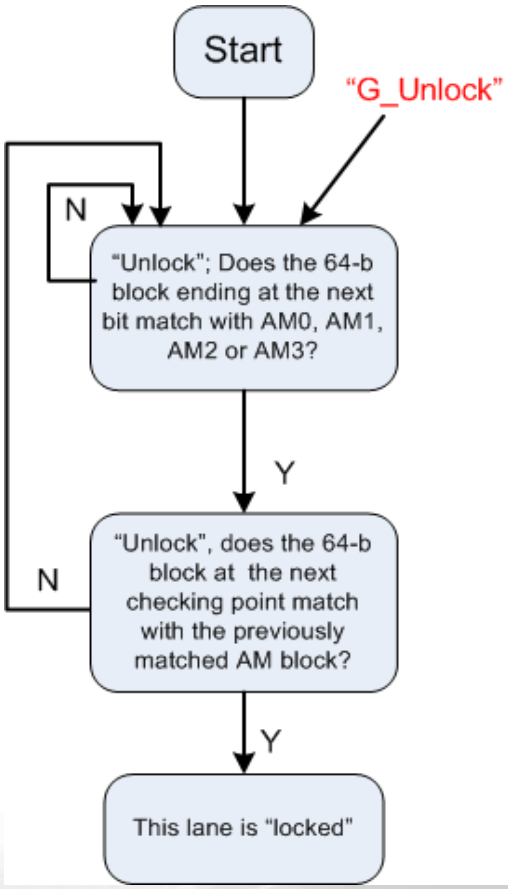
  →Ud→Ud→Fd →Ud→Ud→Fd →Ud→Ud→Fd → Ud→Ud→Fd → Ud→Ud→Ud

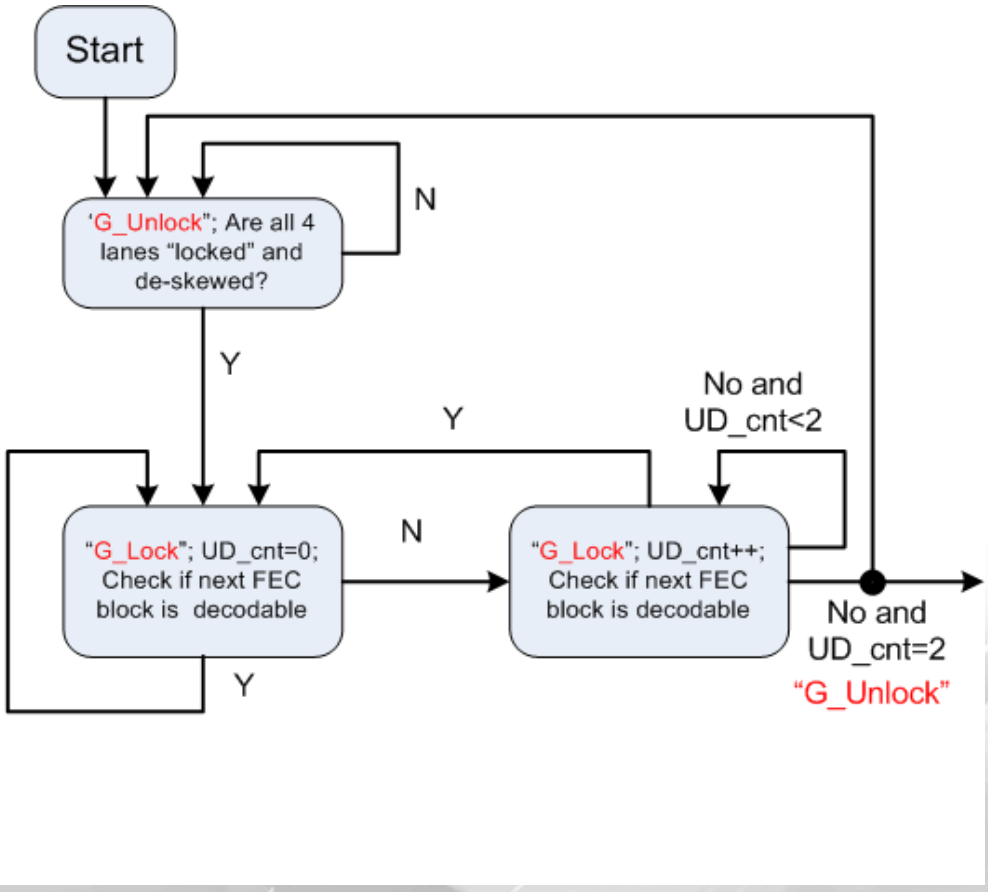
  where "Fd" denotes "false decoding of a FEC block", "Ud" stands for a undecodable FEC block.

- In the above case, we take 15 FEC blocks of transmission time to enter "unlock" state when false aligned. This is more than 2 orders of magnitude shorter than using AM blocks to declare unlock.

AM/FEC Lock SM

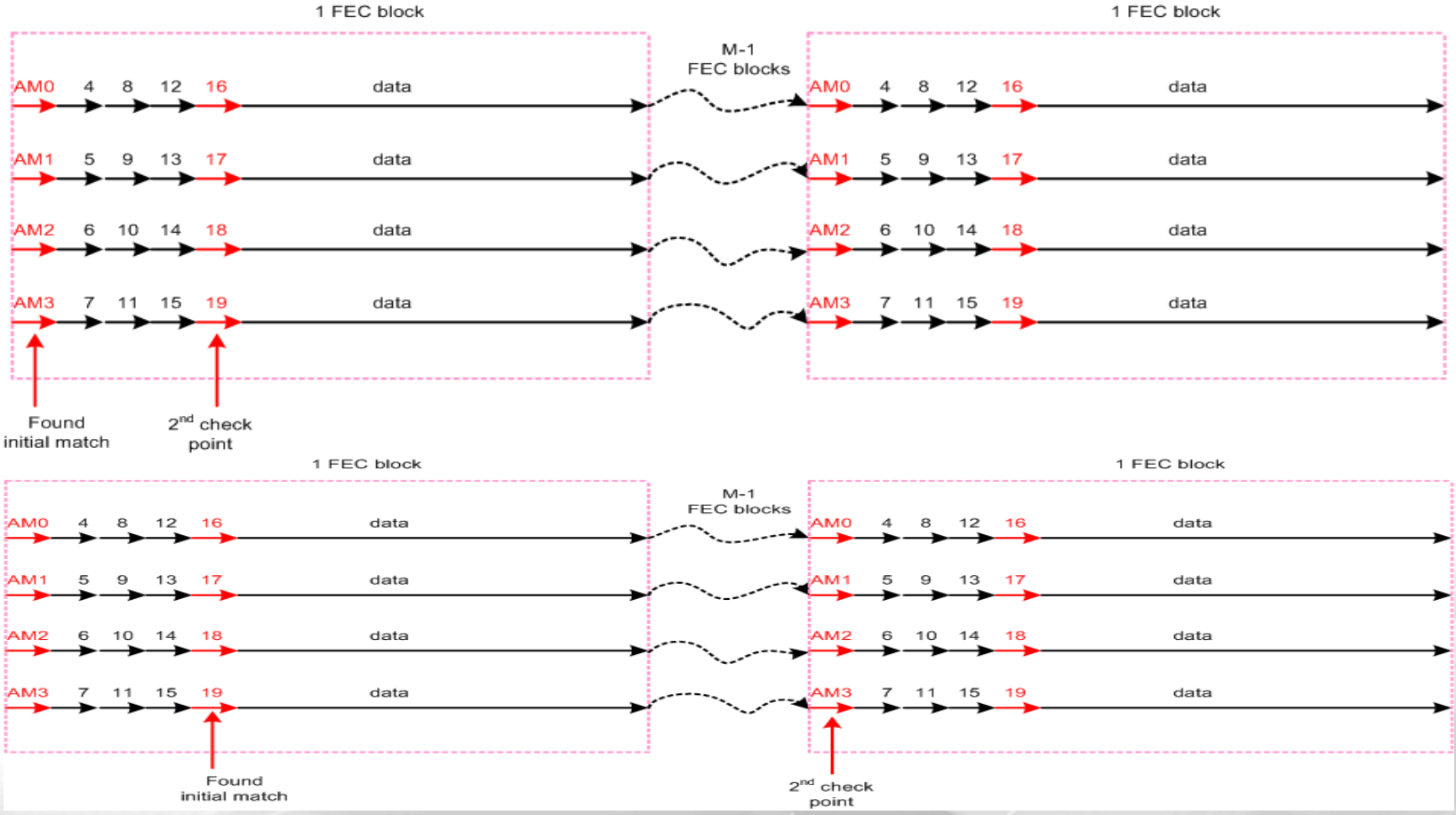
- Left figure shows lock SM for each lane, right hand figure shows SM for global (FEC) lock/unlock.
- The next checking point refers to the 64-b block exactly 4096 FEC blocks away from the previously matched block.



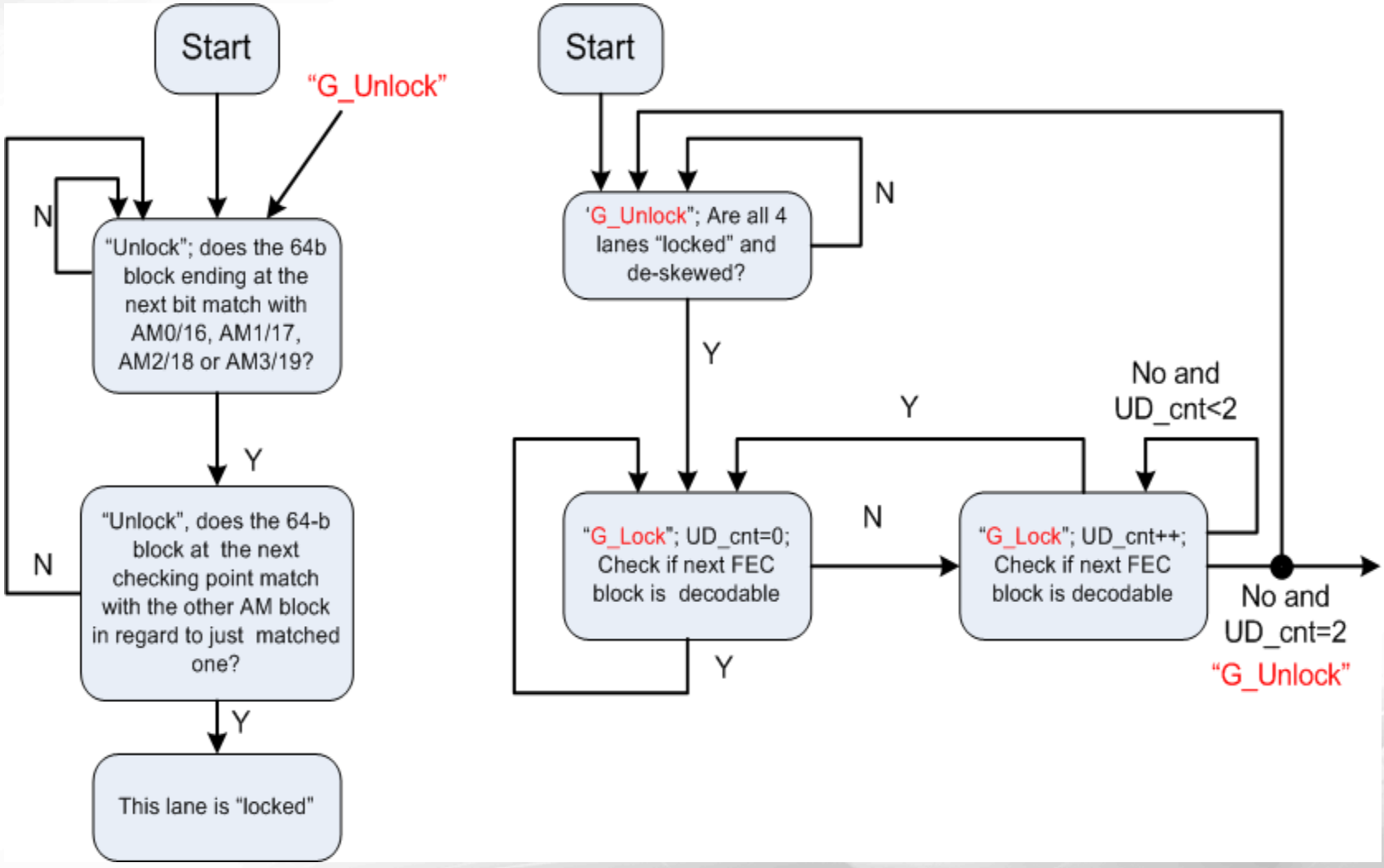


Block Match in EEE Mode

- In EEE mode, we will check block match with two AM blocks (1st and 5th) per AM group of 5 AM blocks (note: either match is counted). Thus we can reduce the worst-case lock time to 3 group delay while keeping the same false alignment probability. The delay between 2 consecutive groups of AM blocks in EEE mode may be as short as 2 FEC blocks (*i.e.*, 100ns).



EEE Mode State Machine



Summary

- Alignment Marker match is defined with a tolerance of symbol errors to mitigate burst errors.
- An optimal tradeoff between low false alignment probability and short worst-case lock time can be obtained when using block match with tolerance of up to 3 4-b symbol errors.
- Using FEC decoder status for unlock detection can greatly speedup the process to enter “unlock” state when falsely aligned.