Downstream Bit Loading Procedure
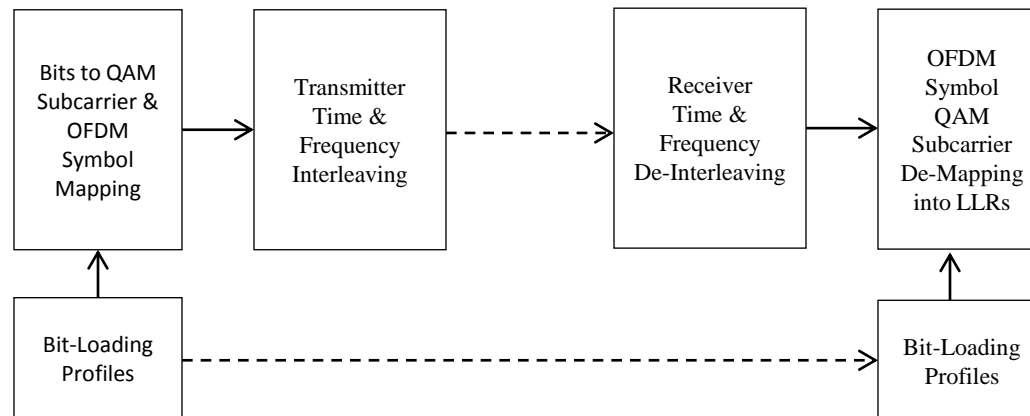
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Outline of DS Bit Loading

- Load bits according to the bit loading profiles.
- The bit loading profile is defined in transmitted subcarrier domain.
- The bit loaded symbols are subject to time and frequency interleaver.
- The scattered pilot pattern changes for each OFDM symbol, which needs to be taken into account during bit loading.
- A placeholder has to be reserved for scattered pilot during bit loading

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Bit Loading and Interleaving

- Diagram from DOCSIS 3.1

```
┌──────────────┐    ┌──────────────┐       ┌──────────────┐    ┌──────────────┐
│ Bits to QAM  │    │ Transmitter  │       │  Receiver    │    │    OFDM      │
│ Subcarrier & │───▶│   Time &     │ ----▶ │   Time &     │───▶│   Symbol     │
│    OFDM      │    │  Frequency   │       │  Frequency   │    │    QAM       │
│   Symbol     │    │ Interleaving │       │De-Interleaving│   │  Subcarrier  │
│   Mapping    │    │              │       │              │    │  De-Mapping  │
│              │    │              │       │              │    │  into LLRs   │
└──────────────┘    └──────────────┘       └──────────────┘    └──────────────┘
        ▲                                                              ▲
        │                                                              │
┌──────────────┐                                               ┌──────────────┐
│ Bit-Loading  │ - - - - - - - - - - - - - - - - - - - - - - ▶ │ Bit-Loading  │
│  Profiles    │                                               │  Profiles    │
└──────────────┘                                               └──────────────┘
```

Summary for DS Bit Loading Procedure

- Profile i: $A_i(k)$, k=0, …, N-1, N=4096/8092
- Let N_l be the set of all indexes excluding continuous pilots, exclusion subcarriers, PLC subcarriers, $B_i(k)$ represents profile for k=0, …, N_l.
- Let $C_i(k)=P^{-1}(B_i(k))$, where P is the frequency interleaver. P^{-1} is the inverse function of P.
- Let $D(k, j)=1$ denote the presence of scattered pilots at subcarrier k and OFDM symbol j before the frequency interleaver. Note: D(k,j) varies for different OFDM symbols.
- Load each of N_l subcarrier of OFDM symbol j with $C_i(k)$ bits, k=0, …, N_l, Whenever hitting D(k,j), that subcarrier is skipped from loading bits.
- D(k,j) needs to be tracked for each frame.
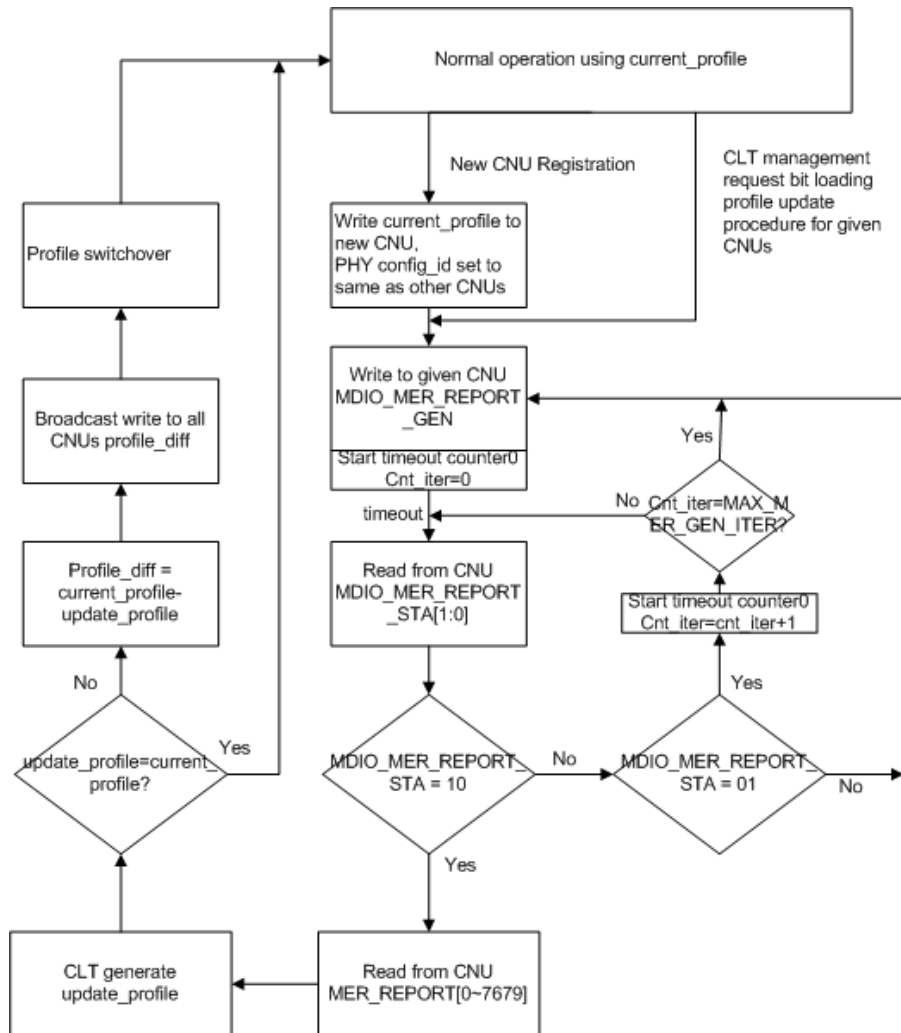
Outline of FDD Bit Loading Profile Update

- Single Modulation Profile for DS FDD (TD #19)
- Each CNU generates different MER measurements, corresponding to different profiles.
- CLT should discretionally choose the single modulation profile that meets the capability of all CNUs, for example, LCD for all profiles.
- The particular bit loading algorithm should be implementation specific.
- The MER measurement is transmitted through the US PHY link channel upon request by CLT.
- The modulation profile is transmitted to each CNU through DS PLC.

When to Update the Bit Loading Profile

- New CNU registration.

- Request from CLT management plane

- CNU may also need to initiate the bit loading profile update for various reasons, for example: bad frame loss ratio

  - CNU is passive, only responds to the instruction from CLT.

  - Use MAC Report message? No, MAC cannot see frame loss.

  - CLT needs to periodically read FER from each CNU.

  CNU_FER[7:0]: $a_2a_1a_0e_4e_3e_2e_1e_0$ represent

  $0.1a_2a_1a_0 * 2\char`^(-e_4e_3e_2e_1e_0)$

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CLT Bit Loading Profile Update

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Data Format of Profile

Code	Modulation	Code	Modulation
0000	OFF	1000	256-QAM
0001	BPSK	1001	512-QAM
0010	QPSK	1010	1024-QAM
0011	8-QAM	1011	2048-QAM
0100	16-QAM	1100	4096-QAM
0101	32-QAM	1101	8192-QAM(optional)
0110	64-QAM	1110	16384-QAM(Optional)
0111	128-QAM		

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Instruction to Write Profile

- Use PLC write instruction
- Each profile needs 7680/4=1920 words. (For 8192FFT)
- CNU needs to maintain two profiles
  - CNU_DS_Profile_A[0~N-1][15:0]
  - CNU_DS_Profile_B[0~N-1][15:0]
  - N = 1920 for 8192 FFT, N = 960 for 4096 FFT
- May have a lot of consecutive carriers with same modulation order
- Use two modes to send bit loading profile
  - Direct Mode: PROFILE_WRITE_MODE=0, the address specify the subcarrier index. Can write 32*4=128 subcarriers for one write command
  - Block Mode: PROFILE_WRITE_MODE=1, the first address specify the start subcarrier index, then followed by the number of subcarriers in a block, the bit loading size for the whole block.

Direct Mode Operation

PLC Instr.	Register	Length (bits)	Count (0~31)	Value	Note:
1	PROFILE_WRITE_MODE	1	0	0	Direct mode
2	CNU_DS_Profile_A/B[k]	13	0~31	vary	Send up to 128 profile element

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Block Mode Operation

PLC Instr.	Register	Length (bits)	Count (0~31)	Value	Note:
1	PROFILE_WRITE_MODE	1	0	1	Block mode
2	PROFILE_WRITE_BLOCK_START	13	0	vary	Start index
3	PROFILE_WRITE_BLOCK_SIZE	13	0	vary	Size of the block of profile elements
4	PROFILE_WRITE_VALUE	4	0	vary	The value of the profile block.

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FDD CNU MIDO Registers

MDIO Registers	Description
CNU_DS_Profile_A[0~N-1][15:0] CNU_DS_Profile_B[0~N-1][15:0]	DS profiles, N = 1920 for 8192 FFT, N = 960 for 4096 FFT. A/B profiles used for hitless switch
MER_REPORT_GEN	1: Start generation of MER report for CNU 0: Not start
MER_REPORT_STA[1:0]	Status of MER reporting 00: Not start 01: Generating a new MER report 10: New MER report ready 11: Error when generating MER report
MER_REPORT[0~Nc-1][15:0]	MER report. 8 bits for each carrier. Each word contains two subcarriers. xxxxxx.xx dB, 0~63.75dB Nc=3840 for 8192FFT Nc=1920 for 4096FFT

FDD CNU Diagram of Bit loading

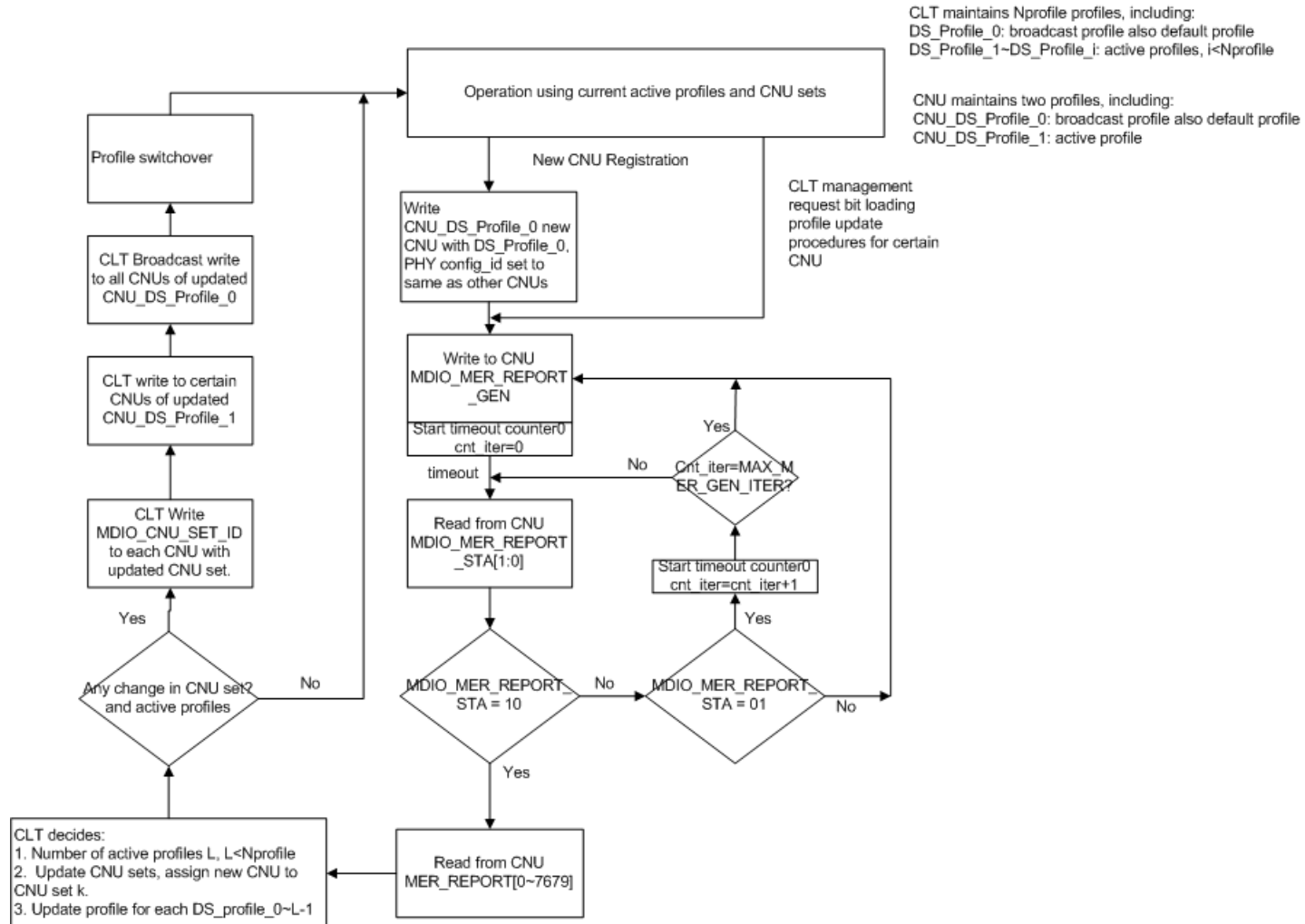IEEE 802.3bn EPoC TF Meeting Nov. 2013
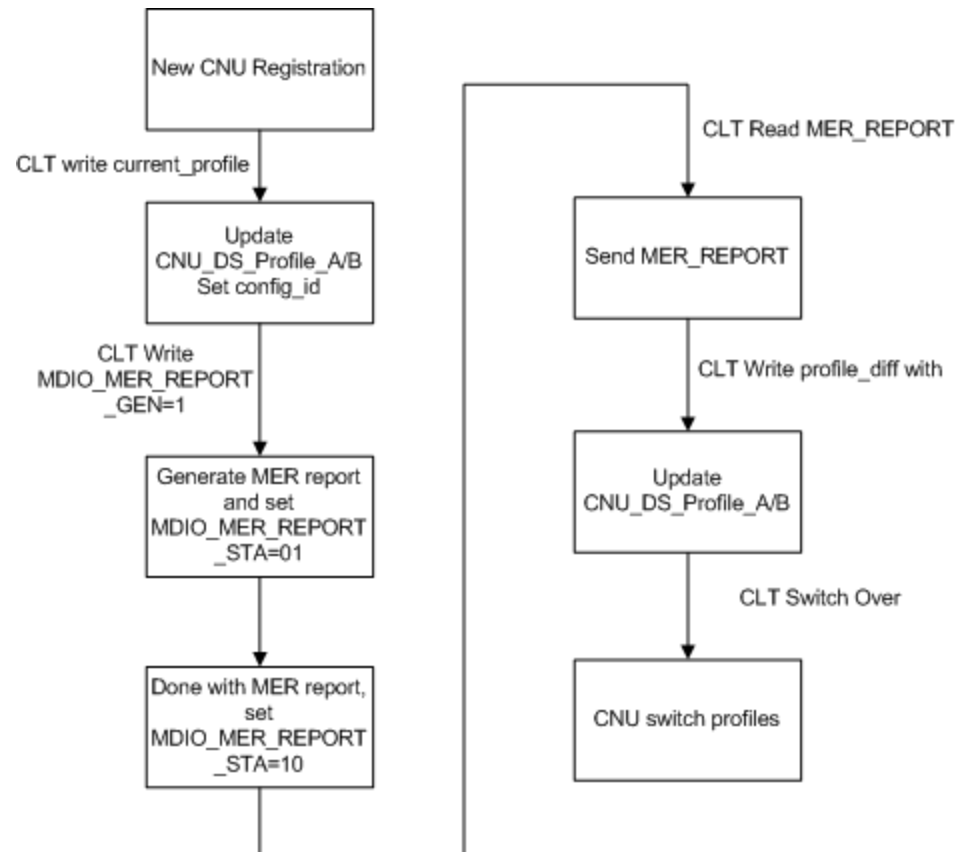
Outline of TDD DS Bit Loading Profile Update

- Support MMP for TDD DS, because TDD DS is in nature bursty. (TD #19)

- CLT maintains up to Nprofile different DS profiles, including one broadcast profile (default profile), and Nprofile-1 individual profiles.

- CLT assigns each CNU in one of Nprofile-1 CNU sets.

- It is implementation specific for CLT to choose the number of active profiles, the CNU sets, and each profile.

-

CLT Behavior for Bit Loading Profile Update

- Upon new registration, the CLT needs to send broadcast profile (default profile) to new CNU.
- CLT shall enable the MER reporting for new CNU.
- After obtaining MER report from CNU, the CLT shall decide
  - Change of active profiles
  - Change of CNU set.
  - Notify each CNU of changed set with profile_update.
- CLT maintains Nprofile profiles, including:
  - DS_Profile_0: broadcast profile also default profile
  - DS_Profile_1~DS_Profile_i: active profiles, i<Nprofile

CLT Diagram for Bit Loading Profile Update

CLT maintains Nprofile profiles, including:
DS_Profile_0: broadcast profile also default profile
DS_Profile_1~DS_Profile_i: active profiles, i<Nprofile

CNU maintains two profiles, including:
CNU_DS_Profile_0: broadcast profile also default profile
CNU_DS_Profile_1: active profile

Operation using current active profiles and CNU sets

New CNU Registration

CLT management request bit loading profile update procedures for certain CNU

Profile switchover

CLT Broadcast write to all CNUs of updated CNU_DS_Profile_0

CLT write to certain CNUs of updated CNU_DS_Profile_1

CLT Write MDIO_CNU_SET_ID to each CNU with updated CNU set.

Yes

Any change in CNU set? and active profiles

No

Write CNU_DS_Profile_0 new CNU with DS_Profile_0, PHY config_id set to same as other CNUs

Write to CNU MDIO_MER_REPORT_GEN

Start timeout counter0 cnt_iter=0

timeout

Read from CNU MDIO_MER_REPORT_STA[1:0]

Cnt_iter=MAX_MER_GEN_ITER?

No

Yes

Start timeout counter0 cnt_iter=cnt_iter+1

Yes

MDIO_MER_REPORT_STA = 10

No

MDIO_MER_REPORT_STA = 01

No

Yes

CLT decides:
1. Number of active profiles L, L<Nprofile
2. Update CNU sets, assign new CNU to CNU set k.
3. Update profile for each DS_profile_0~L-1

Read from CNU MER_REPORT[0~7679]

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TDD CNU MIDO Registers

MDIO Registers	Description
CNU_DS_Profile_0A[0~N-1][15:0] CNU_DS_Profile_0B[0~N-1][15:0] CNU_DS_Profile_1A[0~N-1][15:0] CNU_DS_Profile_1B[0~N-1][15:0]	DS profiles, N = 1920 for 8192 FFT, N = 960 for 4096 FFT. A/B profiles used for hitless switch. CNU_DS_Profile_0x is used for broadcast, and CNU_DS_Profile_1x is used for unicast
MER_REPORT_GEN	1: Start generation of MER report for CNU 0: Not start
MER_REPORT_STA[1:0]	Status of MER reporting 00: Not start 01: Generating a new MER report 10: New MER report ready 11: Error when generating MER report
MER_REPORT[0~Nc-1][15:0]	MER report. 8 bits for each carrier. Each word contains two subcarriers. xxxxxx.xx dB, 0~63.75dB Nc=3840 for 8192FFT Nc=1920 for 4096FFT
CNU_SET_ID_A[2:0]	CNU_SET_ID corresponds to the

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TDD CNU Diagram for Bit Loading

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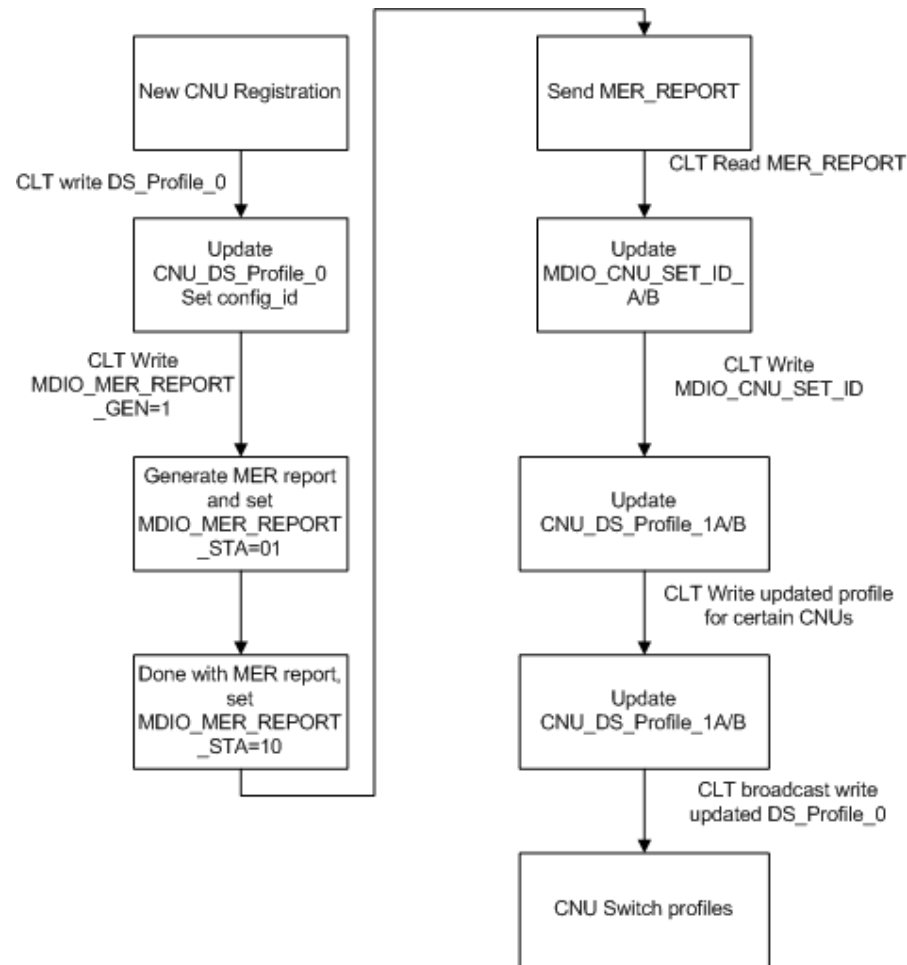
Conclusions

- The EPoC bit loading procedure is similar to that in DOCSIS 3.1.

- Without much help from MAC management message, the bit loading profiles need to be maintained through PLC.

- Instruction sequence regarding the generation and updating of bit loading profiles need to be specified in the standard.

- The implementation of bit loading profile generation at the CLT and MER report generation at CNU are beyond the scope of this TF.