From Control Multiplexer to Gearbox, How Do We Meet MPCP Jitter Requirement?

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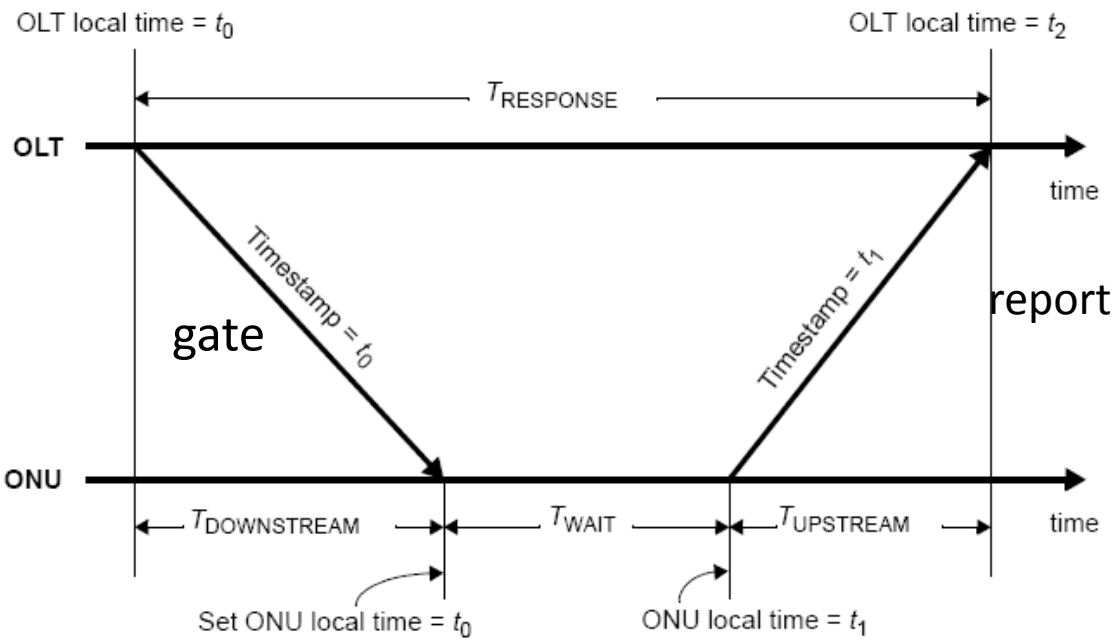
MPCP Timing Requirement

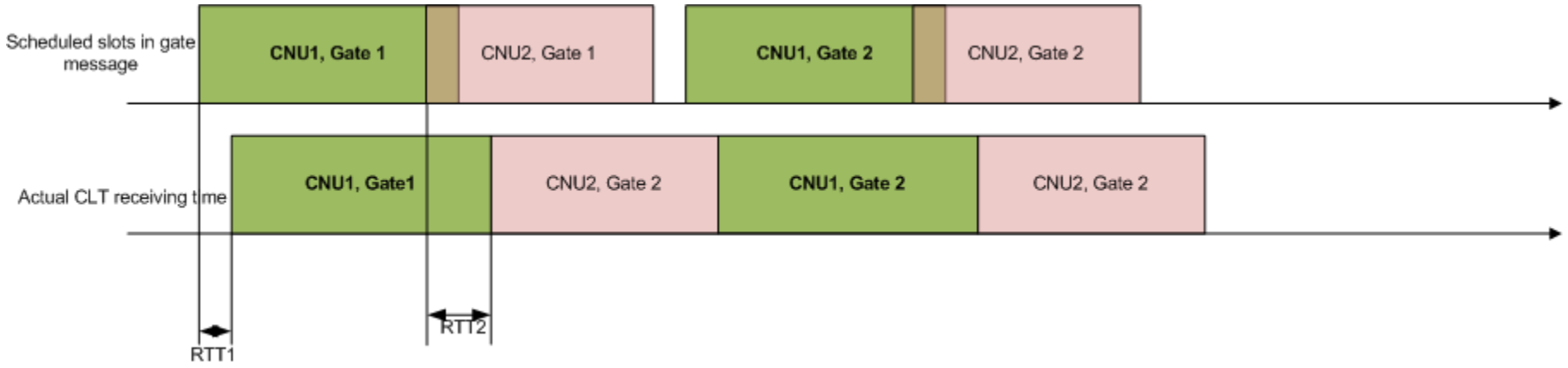
- CLT keeps measuring round-trip time (RTT) by sending gate message and receiving report message



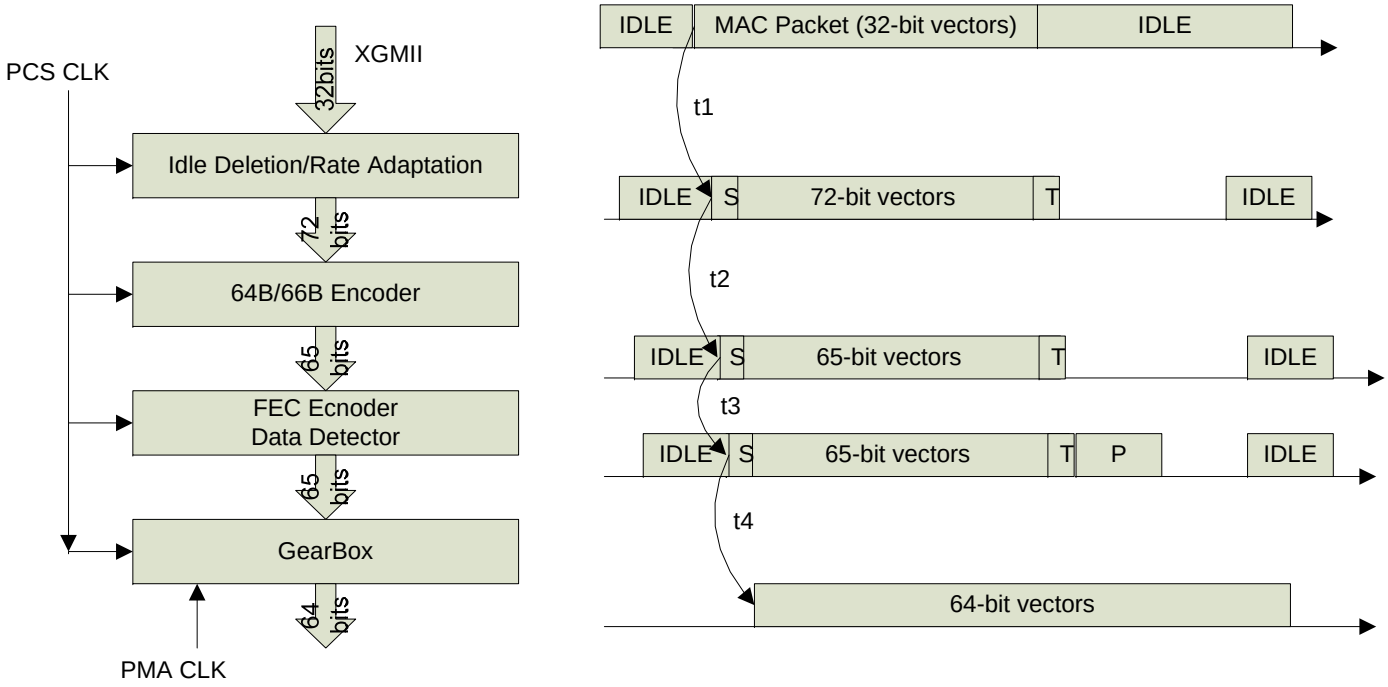
RTT=t2-t1

MPCP Timing Requirement

- MPCP uses RTT from each CNU to schedule time slot for that CNU.
- Precise and jitter-free RTT measurement allows for seamless time slot scheduling.
- Any jitters cause the loss of usable time and that means loss of efficiency.
- Current MPDP only allows for very limited jitters due to implementation (12 TQs, in practice 3~4 TQs, 1TQ=16ns)



PCS Layer Is Jitter-Free



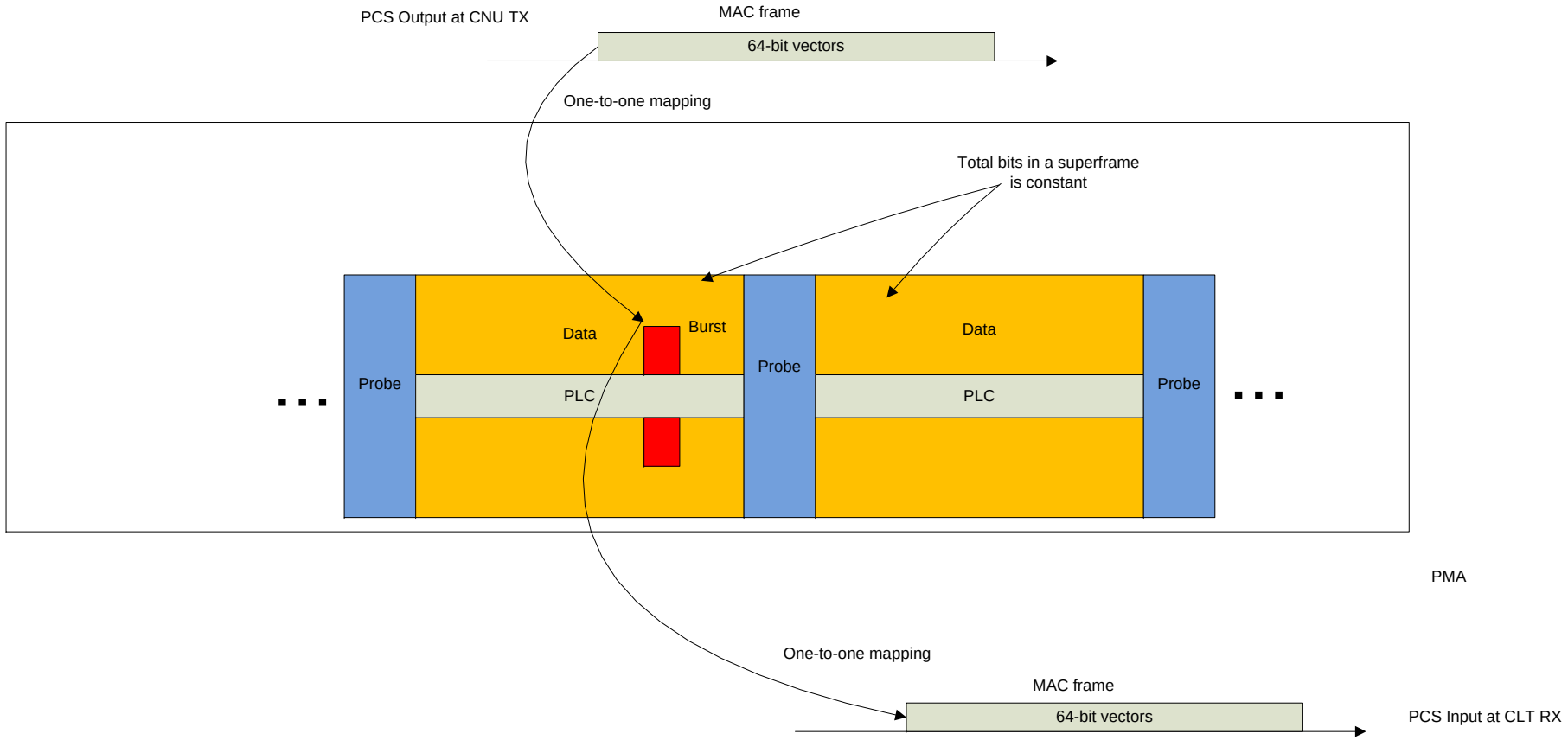
Using the S vector as reference, the PCS modules only incurs fixed processing latency, no jitter occurs if implementation is ideal.

Can we also expect free of jitter for PMA?

PMA Jitter-Free Conditions

- The mapping from PCS output to superframe is one-to-one mapping. Given a S vector (start of MAC frame):
  - Its position in a superframe is unique
  - Inverse mapping at the RX is also unique
  - A buffer in PMA could flat out the rate variation with a superframe
  - The mapping function is same for all CNUs.
- Total number bits in a superframe is constant and same for all CNUs.
  - The mapping function does not change over superframes
  - The amount of bits in one superframe can be considered as large “Pipe” and deliver with a fixed latency.

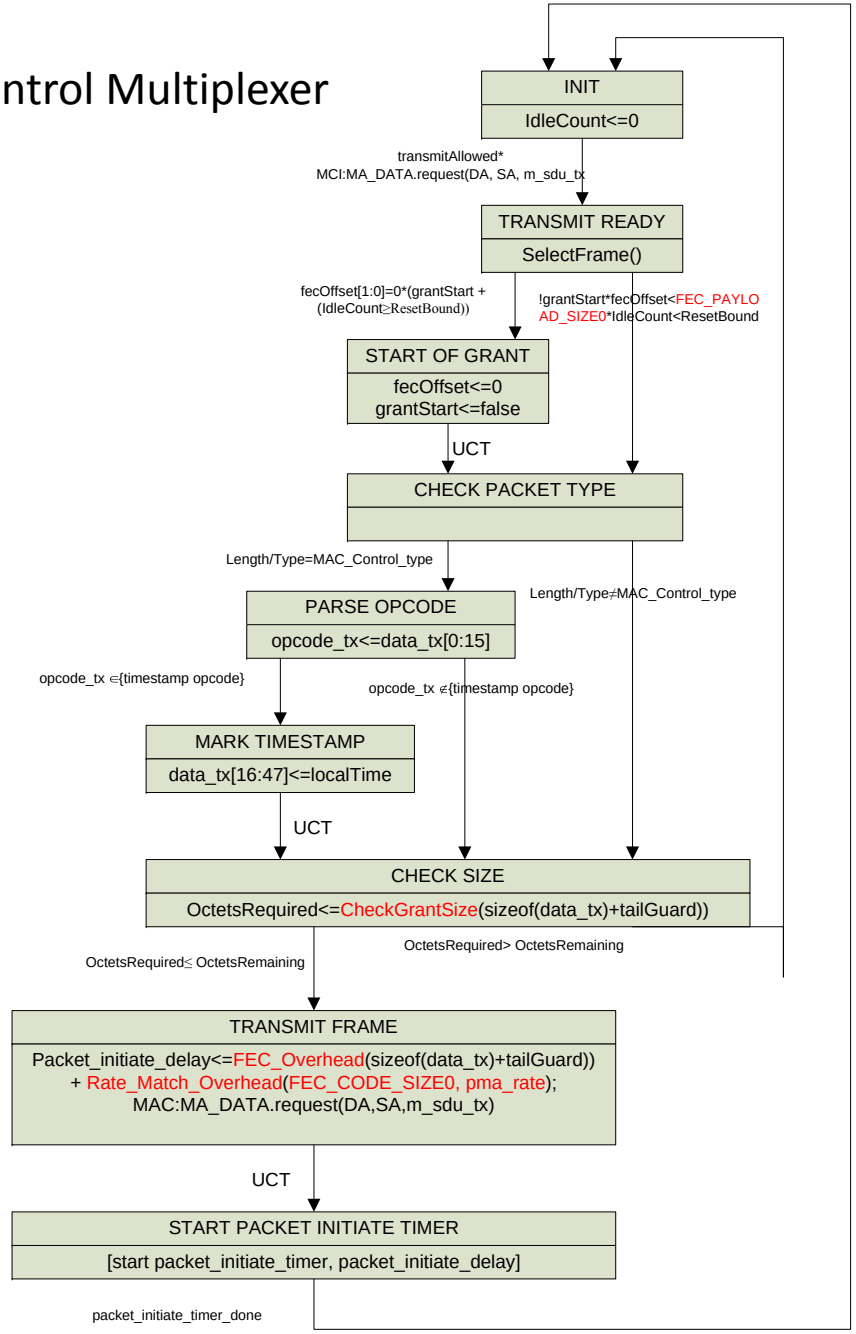
PMA Jitter-Free Conditions



Key Steps of a MAC Frame from MPCP layer to PMA

- MPCP Control Multiplexer
  - Redefine FEC_Overhead() to deal with multiple codeword lengths.
  - Define new Rate_Match_Overhead() to deal with rate matching with PHY rate.
  - Redefine CheckGrantSize() to deal with multiple codeword lengths

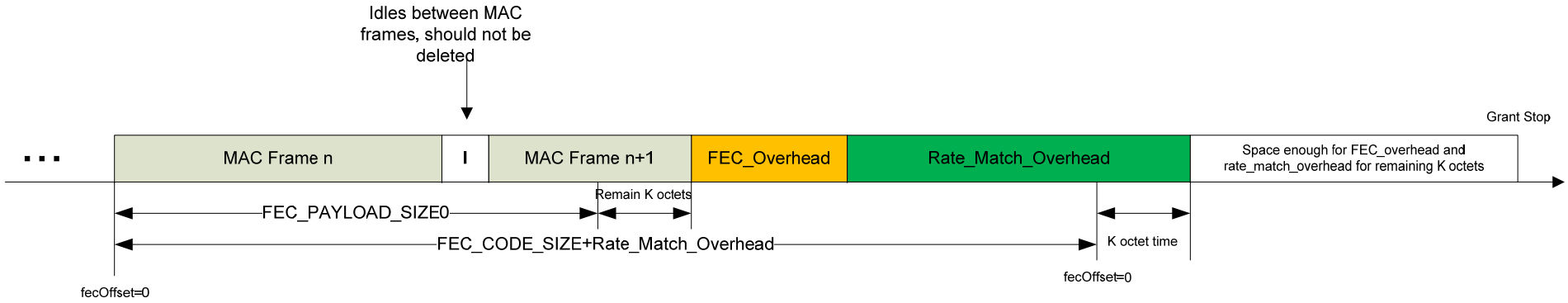
CNU Control Multiplexer



Note:

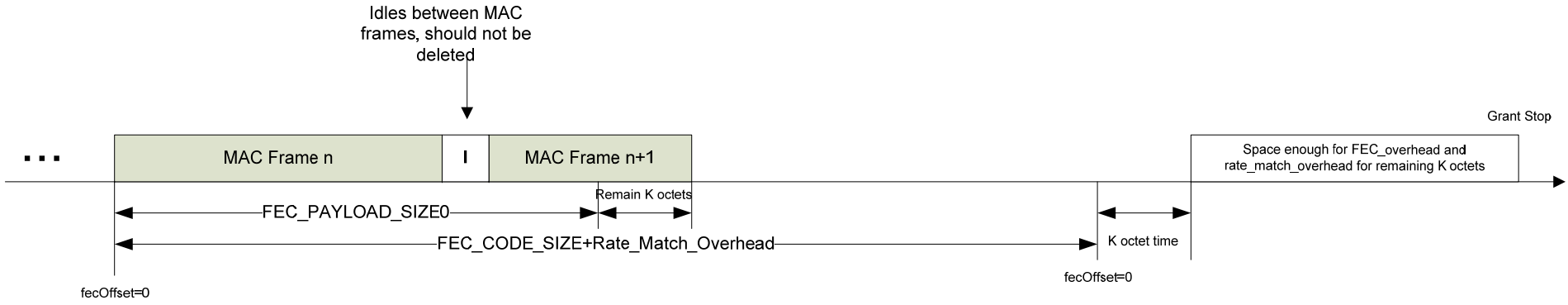
- FEC_PAYLOAD_SIZE0: payload size in octets of the longest FEC code;
- FEC_CODE_SIZE0:codeword size in octets of the longest FEC code;
- fecOffset shall count from 0 to FEC_CODE_SIZE0+Rate_Match_Overhead-1;
- CheckGrantSize() function shall ensure that after transmitting the incoming frame, the remaining space in the grant is still enough to transmit the remaining fecOffset octets.

Example of CNU Control Multiplexer Output



Idle Deletion Output

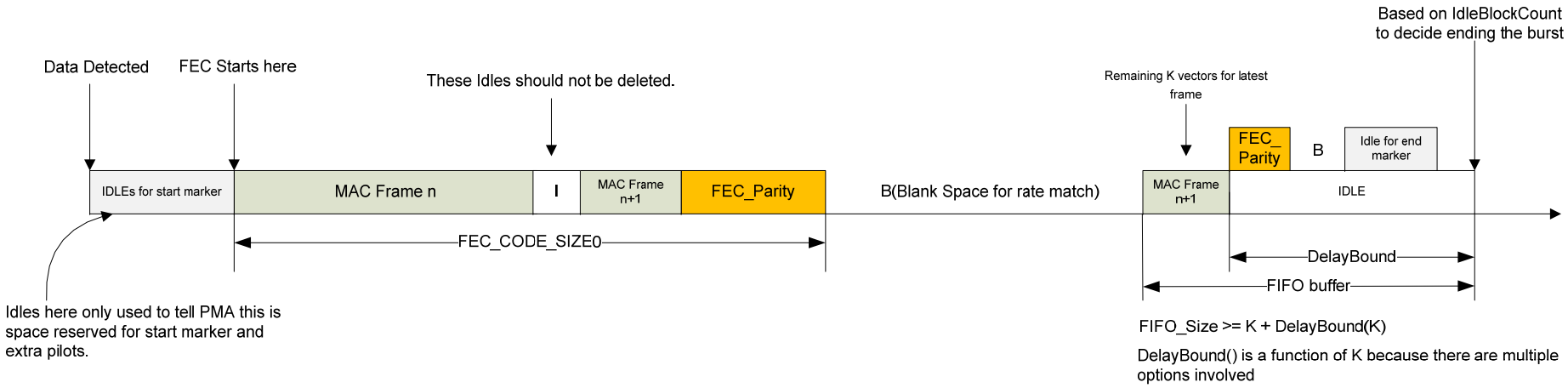
- Idle deletion output is 72-bit vectors
- Idles corresponding to FEC overhead and rate match overhead need to be removed.
- Idles between MAC frames should not be removed



Data Detector

- Insert FEC parity using an FIFO.
- Output code-words as 65-bit vectors.
- Output may be intermittent to leave room for rate conversion at the GearBox.
- Insert special placeholder symbols or control signals to indicate the overhead for start marker and end marker, as well as extra pilot overhead.

Example of Data Detector Output

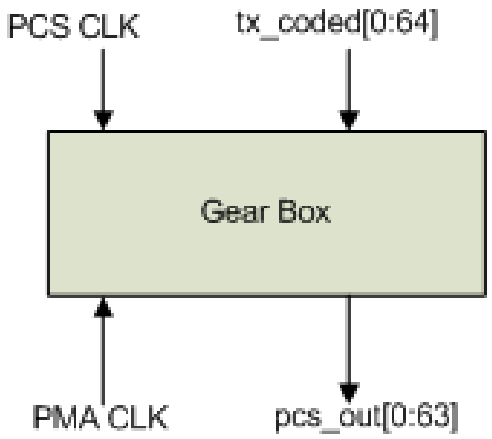


Note:

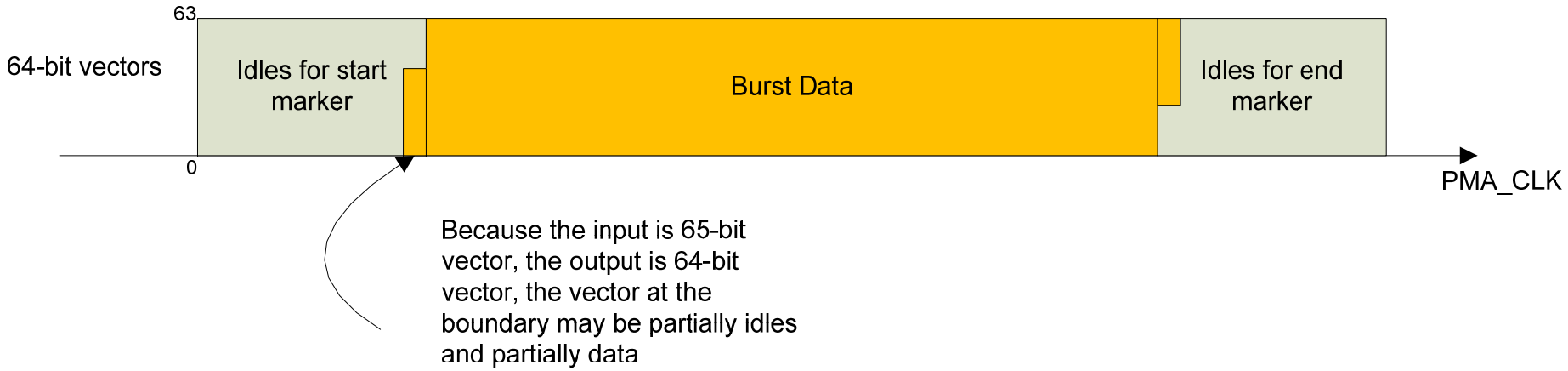
1. Idle deletion needs to remove more idles beyond FEC overhead to adapt to the PMA rate.
2. Idles between the frames should NOT be removed.
3. Towards the end of burst, idle deletion should be specially handled, because of multiple codeword length. Idles need to be deleted after the end of burst is decided.

Gear Box

- Input: data detector output, 65-bit intermittent vectors driven by PCS CLK
- Output: 64-bit or 32-bit vectors constant rate stream driven by PMA CLK. (the bus width of gearbox output should not be limited to these options.)
- PMA rate = superFrameBits/superFrameClocks



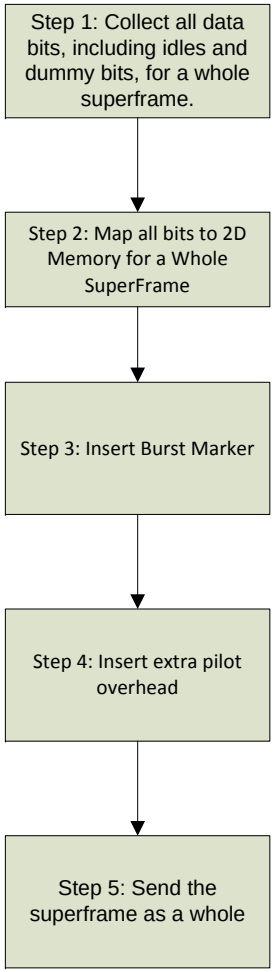
Typical Output of Gear Box



PMA 1D-2D Mapping

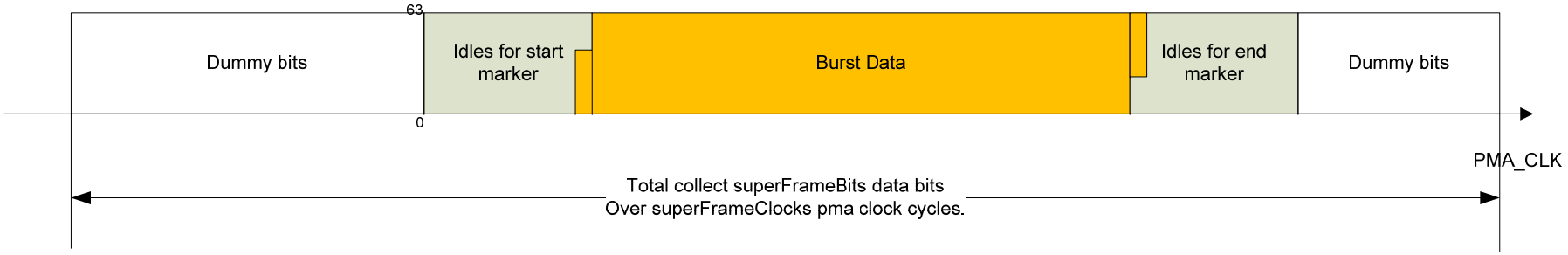
- The gearbox output is still one-dimensional.
- PMA modulator shall buffer the gearbox output data and map them to 2-D symbols.
- We use a “dumb modulator” to demonstrate the operation of modulator.
- Actual implementation could be “smarter” by using pipe-lined structure to save memory.

PMA “Dumb Modulator

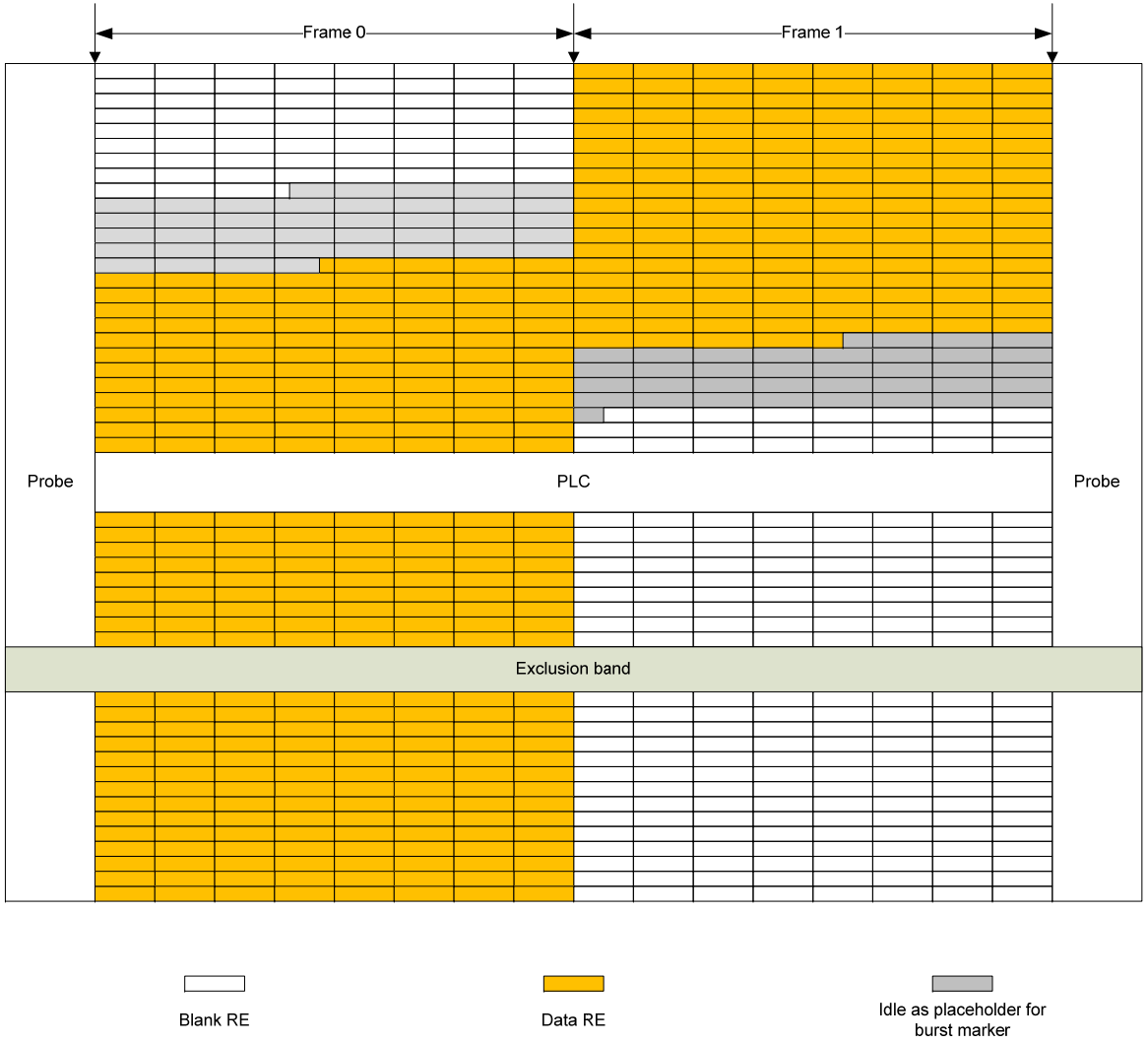


Example of “Dumb” Modulator

Step 1: Collect all bits for a superframe

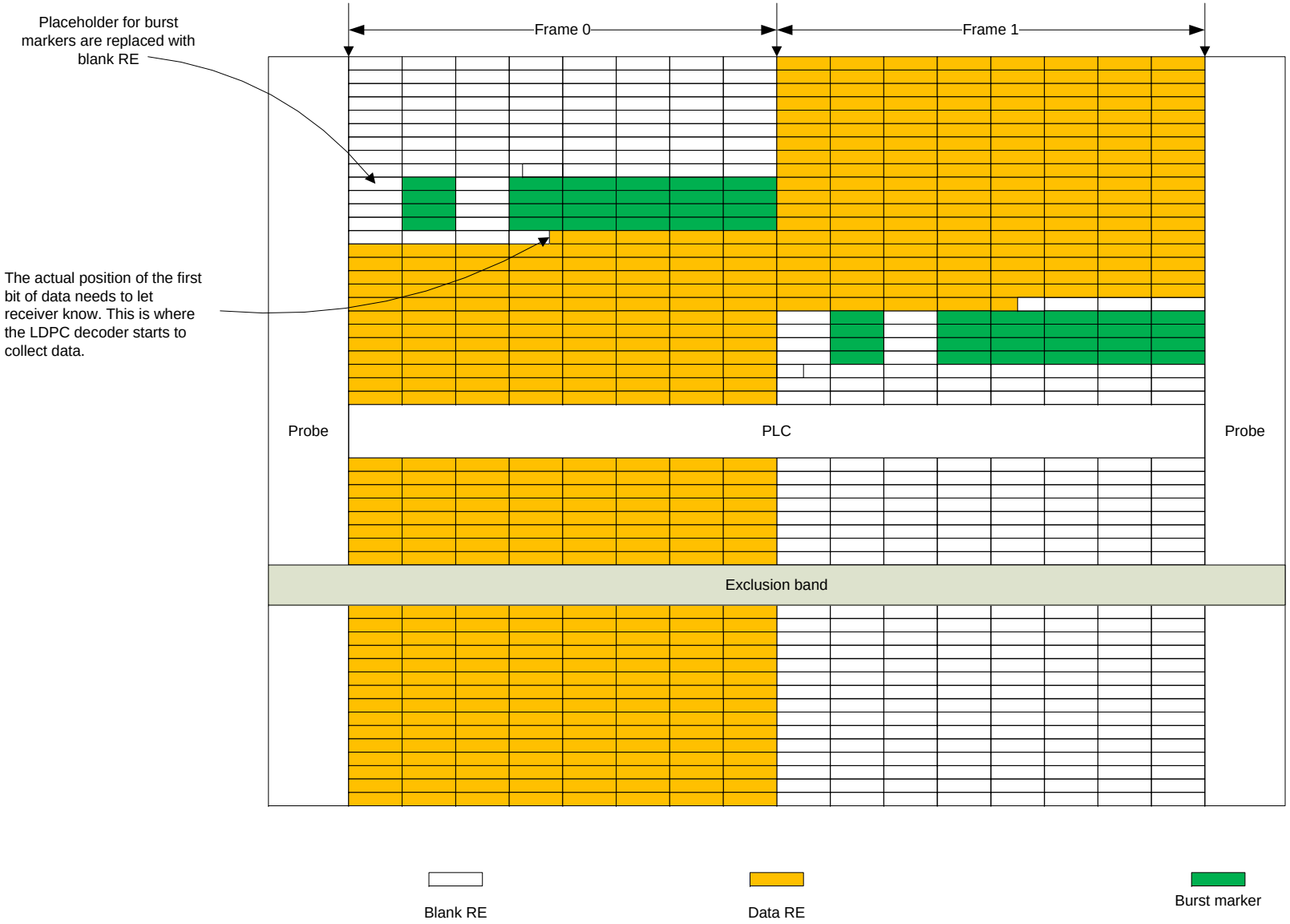


Step 2: Map all bits to 2D Memory for a Whole SuperFrame



Note:
For illustration only.
Does not show
fixed pilot overhead

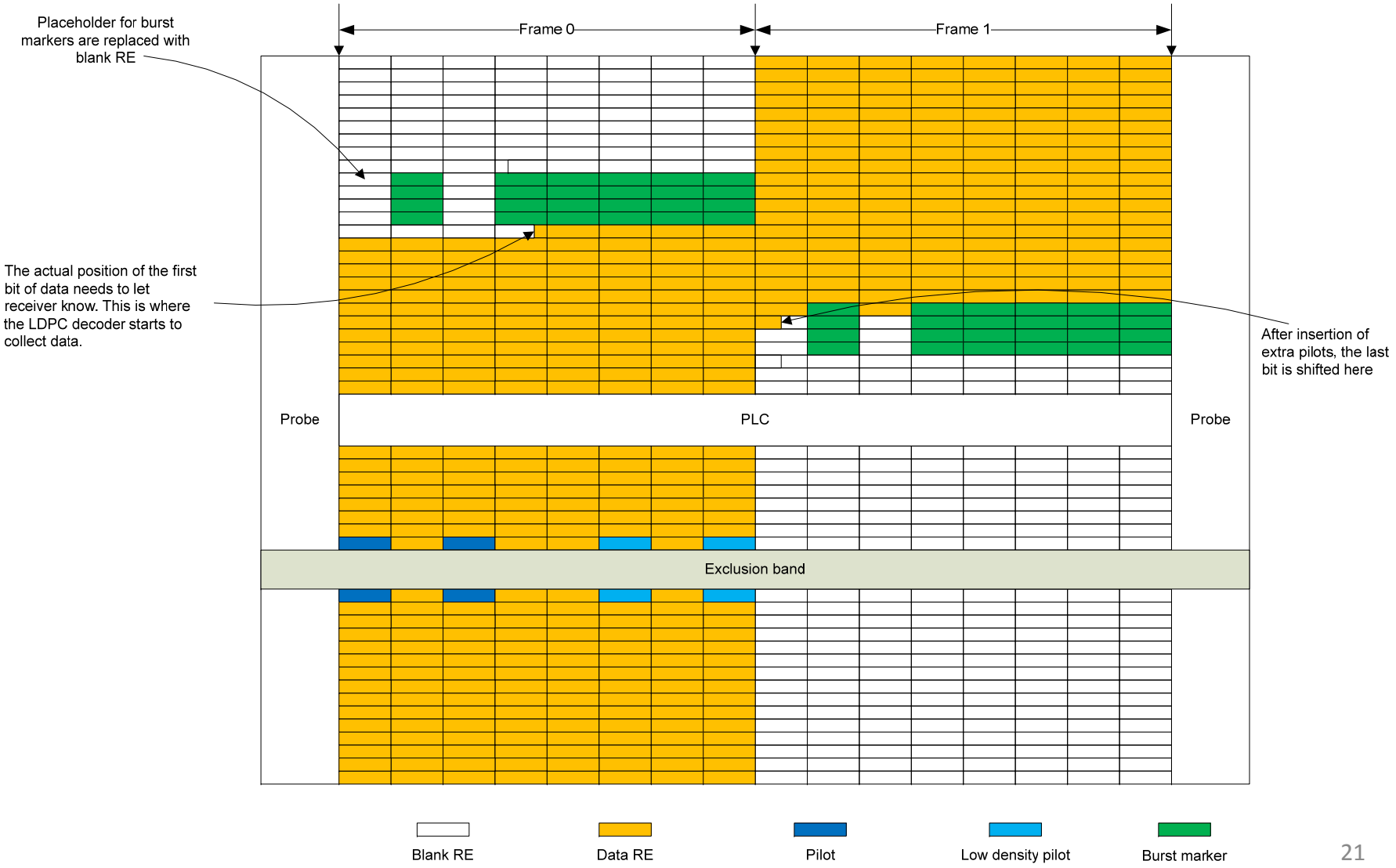
Step 3: Insert Burst Marker



Step 4: Insert extra pilot overhead

- Need to shift burst data to leave room for extra pilot overhead.
- Definition of extra pilot overhead
  - Most pilots are fixed in the 2-D grid
  - Some pilots are extra for protecting the exclusion band or band edge. These are extra pilot overhead
- Rules to shift the burst data
  - The first bit of burst data may not be shifted, since it bears the information of the start of burst data. The position of the first bit should be let known to the receiver.
  - The burst data can shift toward the end marker to leave room for extra pilot overhead.
  - The amount of extra pilot overhead in terms of RE and the equivalent number of bits should be known to the data detector, i.e. data detector needs to calculate the max amount of overhead needed.
  - Things would be much easier if no extra pilot overhead

Example of Step 4 Operation



About the Position of the First Bit

- Any random shift of the first bit position will cause jitter for the timestamp at report message.
  - For example, alignment of the first bit to RE, max shift = 9 bits (for 1024QAM)
  - The lower the upstream bit rate, the higher the jitter.
  - For 100Mb/s, 9 bits amounts to 90ns or 5.6TQ
  - Furthermore, this shift will cause the receiver to reset the alignment of 65-bit boundary for each burst it receives.
- Solutions:
  - Do not shift the first bit of burst data to align with RE.
  - Establish a fixed and known relationship of the 65 bit boundary to the super frame.
  - For example, the first bit of a superframe aligns with the 65 bit boundary for all CNUs. And the total number of bits in a superframe is an integer multiple of 65 bits.
  - The exact position of the first bit of the burst data should be let known to the receiver.
  - The gearbox output or pcs output can be also 65 bits to make things easier.

Conclusion

- From the introduction of this “dumb” modulator, it is possible to achieve fixed delay and zero jitter.
- The total bits in a superframe has to be constant number and same for all CNUs. A change of this number will cause restart of Tx at all CNUs and CLT Rx.
- The mapping of burst data into 2-D structure shall be one-to-one mapping or “bi-jection”.
- It is beneficial to establish a fixed relation between superframe and the 65-bit boundary.
- The exact position of the first bit in a burst should be let known to the CLT receiver.