Why the Half-Duplex MAC Doesn't Work for P2MP
(And what to do about it!)

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How we got here!

- **D2.0 Comment #337:** Inter-Packet Gap (IPG) is enforced by MAC deferral process. But the OLT has multiple independent MACs. IPG is not enforced between packets from different MACs.

Solution adopted in September meeting in Portonovo:

- P2MP should use half-duplex (CSMA/CD) MAC

- Extend PCS to control MACs in parallel using Carrier Sense (CRS) signal

Half-Duplex Impact on Efficiency

- Half-duplex MAC uses carrier extension

- Shorter frames are extended to minimum size of 512 octets (clause 4.2.3.4)
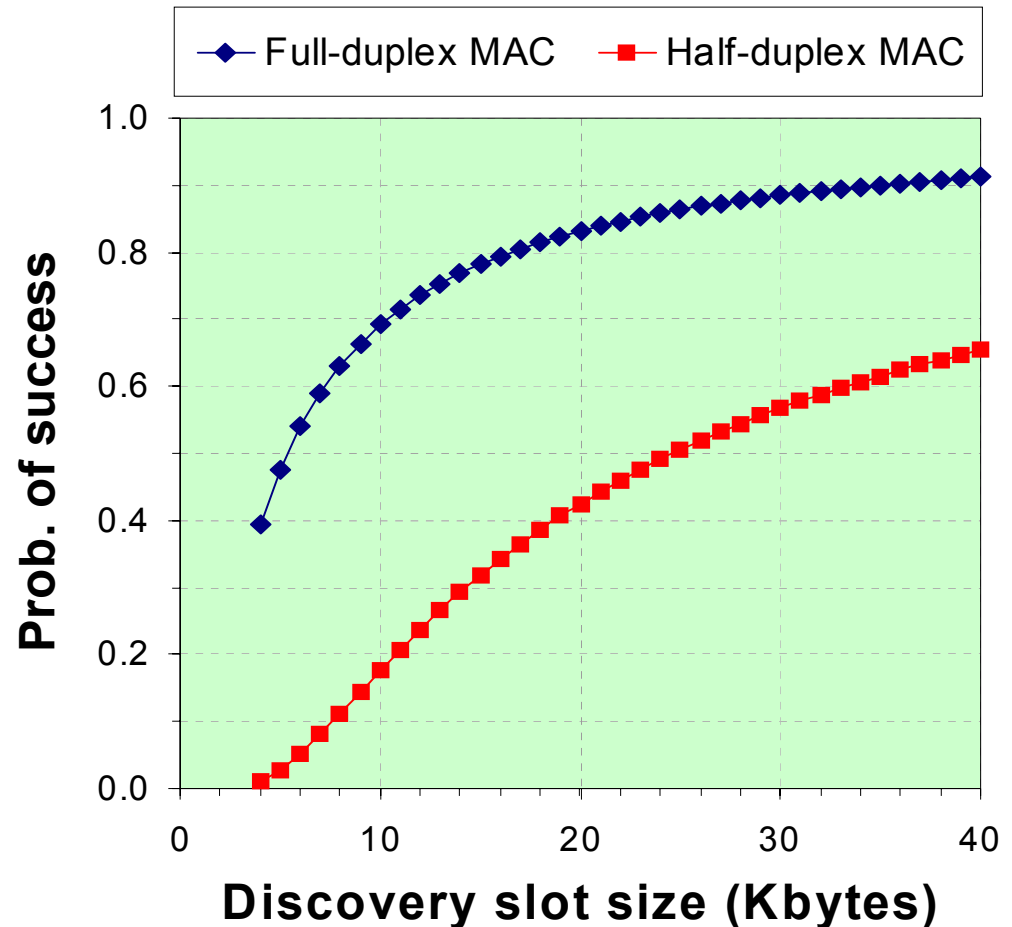
- Detrimental impact on efficiency

	Worst-case (only 64-byte packets)	Empirical packet size distribution
Carrier extension overhead	84%	31.6%
Overall EPON efficiency	10.2%	55.6%

Setup parameters: Number of ONUs = 32, Cycle time = 1 ms, Guard band (including laser_on, T_{AGC}, and T_{CDR}) = 1 μs, No frame delineation loss, No discovery overhead, One grant per ONU per cycle

Half-Duplex Impact on Discovery

- Every REGISTER_REQ message will be extended to 512 octets

  – Probability of successful discovery is considerably lower

  – Discovery window should be very large, or many more discovery attempts required

Probability that an ONU will be discovered in current attempt if a total of 16 ONUs contend for discovery

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Half-Duplex Impact on Grants

- OLT doesn't know the length of carrier extension or individual packet sizes in the reported QueueLength. How can the OLT account for net user bandwidth?

- Subscribers are penalized for carrier extension overhead.

- Bandwidth guarantees per subscriber are very difficult or not possible (overhead depends on packet size mix).

Bursting Helps: ONU Efficiency

- ONU transmits entire grant as one burst (up to 8k octets). Only the first frame in a burst is extended, if needed.

- Bursting improves upstream efficiency:

	Worst-case (only 64-byte packets)	Empirical packet size distribution
Carrier extension overhead	11.3%	6.3%
Overall EPON efficiency	63.5%	85.2%

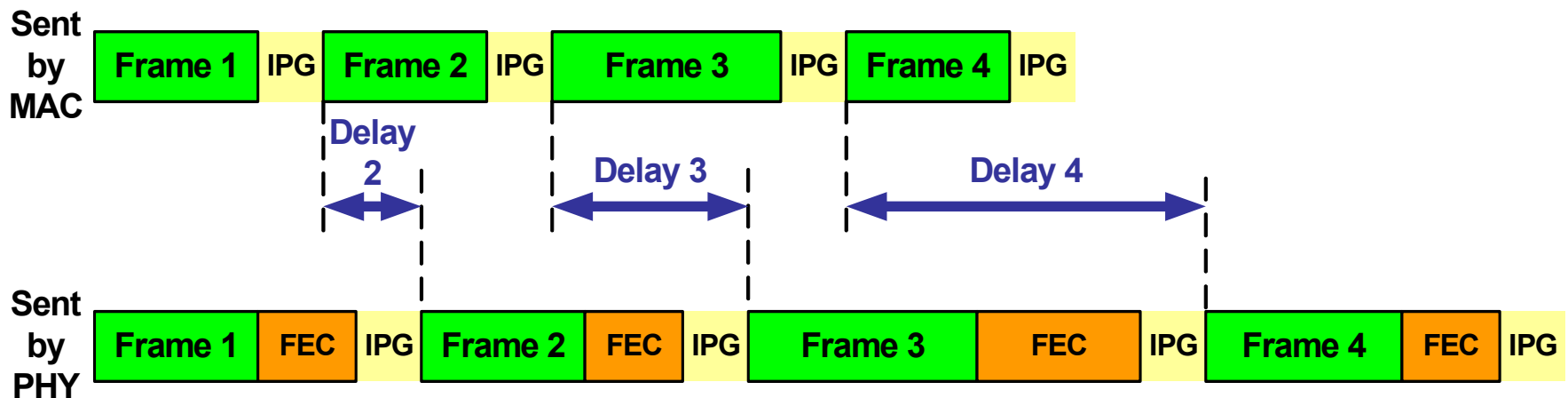# Bursting Doesn't Help:

- OLT Efficiency

  - Downstream is unlikely to burst from the same MAC (to the same ONU)

- Registration

  - REGISTER_REQs are not transmitted in bursts

- Grants

  - Bursts do nothing to remove the variability of the first packet carrier extension

Bursting+FEC breaks MPCP

- PHY buffer must accept entire burst while appending FEC parity to individual packets.

- Packet delay in PHY buffer is equal to the amount of parity symbols required by preceding packets.

- MPCP timing mechanism relies on constant packet delay between OLT and ONU. Variable delay in PHY breaks MPCP!

Sent by MAC

| Frame 1 | IPG | Frame 2 | IPG | Frame 3 | IPG | Frame 4 | IPG |

Delay 2

Delay 3

Delay 4

Sent by PHY

| Frame 1 | FEC | IPG | Frame 2 | FEC | IPG | Frame 3 | FEC | IPG | Frame 4 | FEC | IPG |

Decision tree

```
                        ┌─────────────────┐
                        │      Start      │
                        └─────────────────┘
                         /               \
                        /                 \
        ┌──────────────────────┐    ┌──────────────────────┐
        │   Half-duplex mode    │    │   Full-duplex mode    │
        └──────────────────────┘    └──────────────────────┘
              /            \                    |
             /              \                   ↓
  ┌────────────────────┐  ┌────────────────────┐   • **No extra overhead**
  │  Carrier Extention  │  │ No carrier extension │
  └────────────────────┘  └────────────────────┘   • **Problem is solved
       /         \                 |                    in MPCP**
      /           \                ↓
 ┌──────────┐  ┌──────────────┐   ✖
 │ Bursting │  │  No bursting  │
 └──────────┘  └──────────────┘   • **Requires changes
      |              |                 to Clause 4**
      ↓              ↓
      ✖              ✖
```

• **Downstream is inefficient**

• **Discovery is very inefficient**

• **FEC adds variable delay in PHY**

• **Very inefficient**

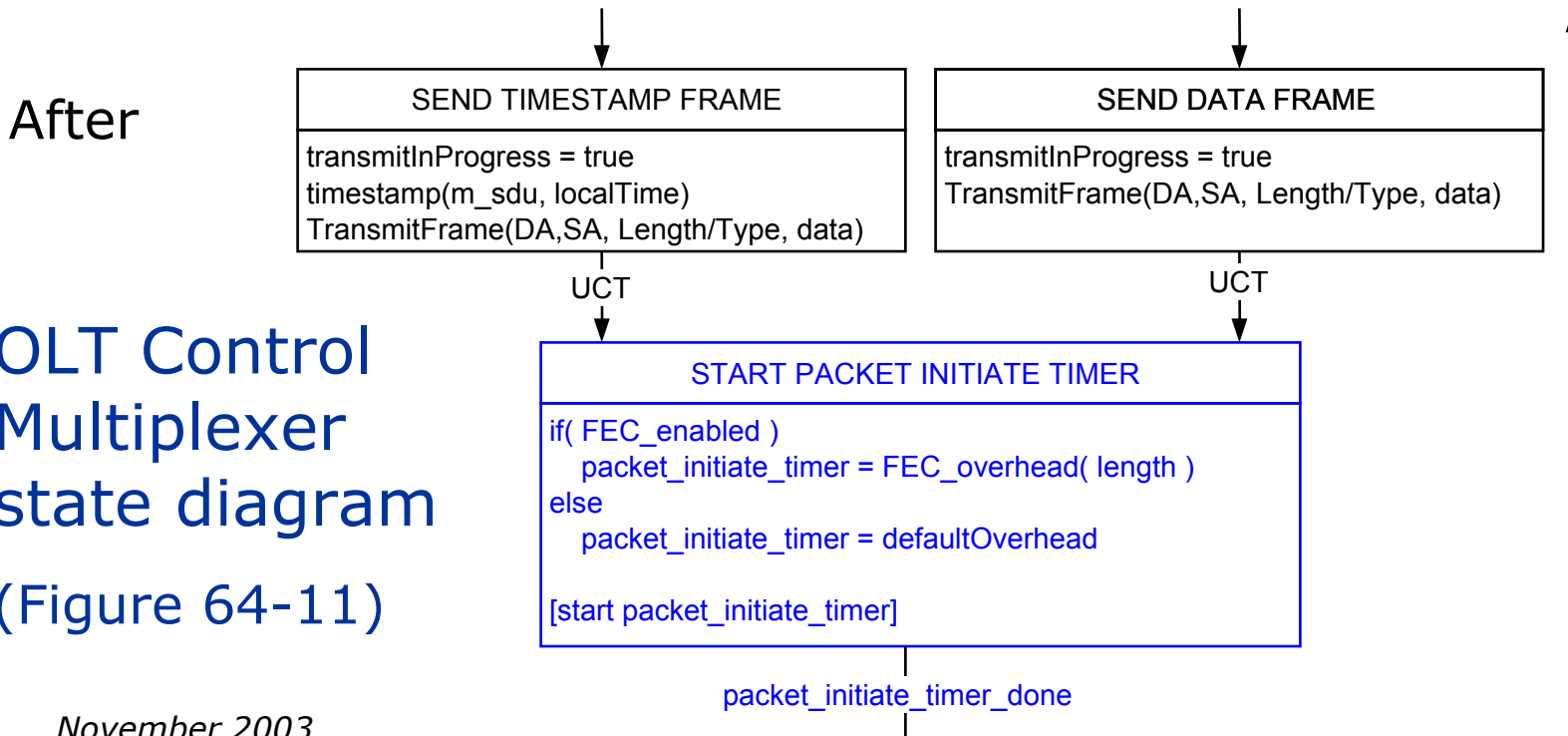• **Large overhead for MPCPDU**
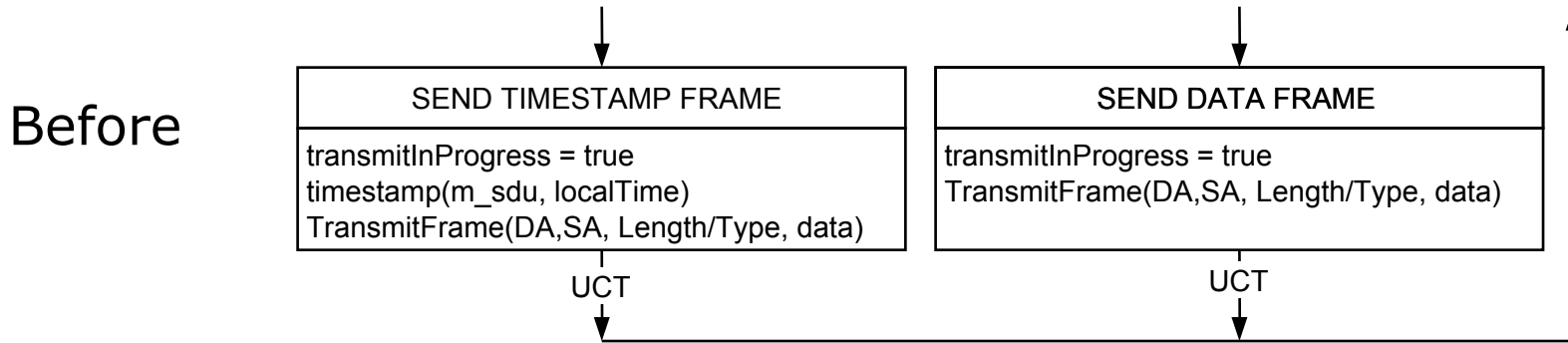
• **Variable overhead depends on packet sizes**

Proposed Solution

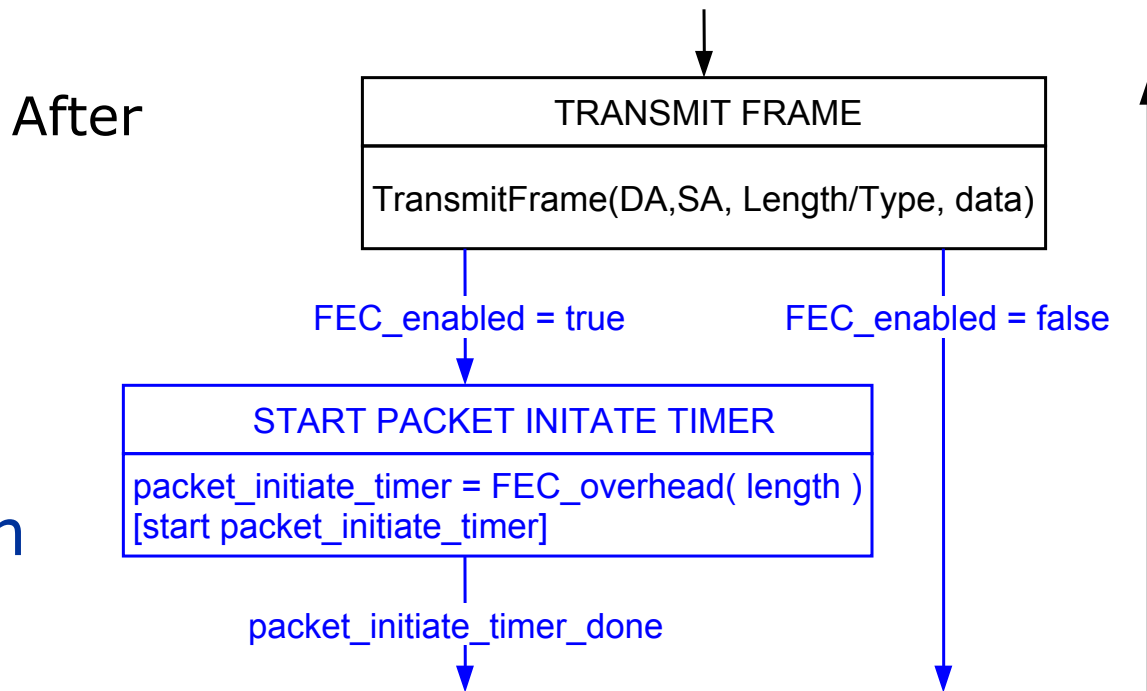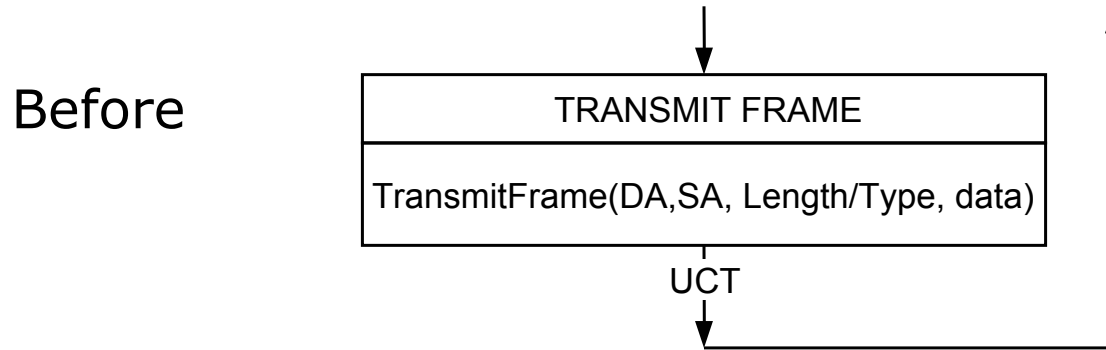- Only MPCP has a top view of all the logical links, therefore, only MPCP can properly time packet transmissions.

- Multi-Point MAC Control times packet starts

  - Ensures appropriate operation and efficiency

  - Lower layers create IPG exactly as they would with intermittent traffic on any full duplex link

- Removes throughput inefficiencies

- Removes discovery inefficiencies

- Compatible with frame-based FEC

Necessary changes in OLT

Before

SEND TIMESTAMP FRAME
transmitInProgress = true timestamp(m_sdu, localTime) TransmitFrame(DA,SA, Length/Type, data)

UCT

SEND DATA FRAME
transmitInProgress = true TransmitFrame(DA,SA, Length/Type, data)

UCT

After

SEND TIMESTAMP FRAME
transmitInProgress = true timestamp(m_sdu, localTime) TransmitFrame(DA,SA, Length/Type, data)

UCT

SEND DATA FRAME
transmitInProgress = true TransmitFrame(DA,SA, Length/Type, data)

UCT

OLT Control Multiplexer state diagram

(Figure 64-11)

START PACKET INITIATE TIMER

if(FEC_enabled)
   packet_initiate_timer = FEC_overhead(length)
else
   packet_initiate_timer = defaultOverhead
 	
[start packet_initiate_timer]

packet_initiate_timer_done

Necessary changes in ONU

Before

TRANSMIT FRAME
TransmitFrame(DA,SA, Length/Type, data)

UCT

ONU Control Multiplexer state diagram

(Figure 64-12)

After

TRANSMIT FRAME
TransmitFrame(DA,SA, Length/Type, data)

FEC_enabled = true   FEC_enabled = false

START PACKET INITATE TIMER
packet_initiate_timer = FEC_overhead(length) [start packet_initiate_timer]

packet_initiate_timer_done

Conclusion

- Half-duplex MAC creates more problems than it solves

- All problems can be solved in MPCP with minimal changes

- The proposed solution keeps full-duplex MAC and does not change Clause 4
  - No changes to deference
  - No changes to IPG methods