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Technical Feasibility of Gigabit Ethernet PONs using Existing 802.3 MAC Layer

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Abstract

This contribution is intended to address the issue of technical feasibility for Gigabit Ethernet Passive Optical Networks to enable the EFM activity to be established as a task force leading to an enhanced 802.3 standard addressing Gigabit Ethernet PONs.

We address several areas of technical challenge and cite precedents or propose example solutions. These proposals are not intended to prejudice later task force discussions, but rather to show that there are no insurmountable technical issues which prevent the standardisation and successful implementation of a Gigabit PON, based on the 802.3 standard and without changing the MAC layer.

Areas of technical development

- **Gigabit Ethernet PON shared media access protocol**
  – Add functionality without changing existing MAC
- **Plug and play**
  – Automatic identification and enabling of new subscribers upon attachment
- **Ranging and efficiency**
  – Balance between complexity and performance in a packet based world
- **Fibre network**
  – Components and optical signal attenuation plus new requirements
- **Optical devices**
  – Meeting the optical power budget and other requirements
- **Management issues**

GEPON protocol

- **Several contributions have proposed viable protocols for Ethernet PONs**
- **Downstream frames are broadcast to all subscribers and no additional protocol is needed**
- **Enhancements to 802.3 for upstream traffic can be confined to the MAC Control layer and PHY, i.e. no change to existing MAC**
- **Proposal:**
  - Extend definition of MAC flow control frames to allow transmission of directed pause commands from headend to subscriber to control upstream TDMA
  - Action on receipt of directed pause frames is already defined
  - Traffic flow from individual subscribers can be regulated according to the allocated proportion of total available bandwidth
- **Ranging can be introduced to improve efficiency if required**

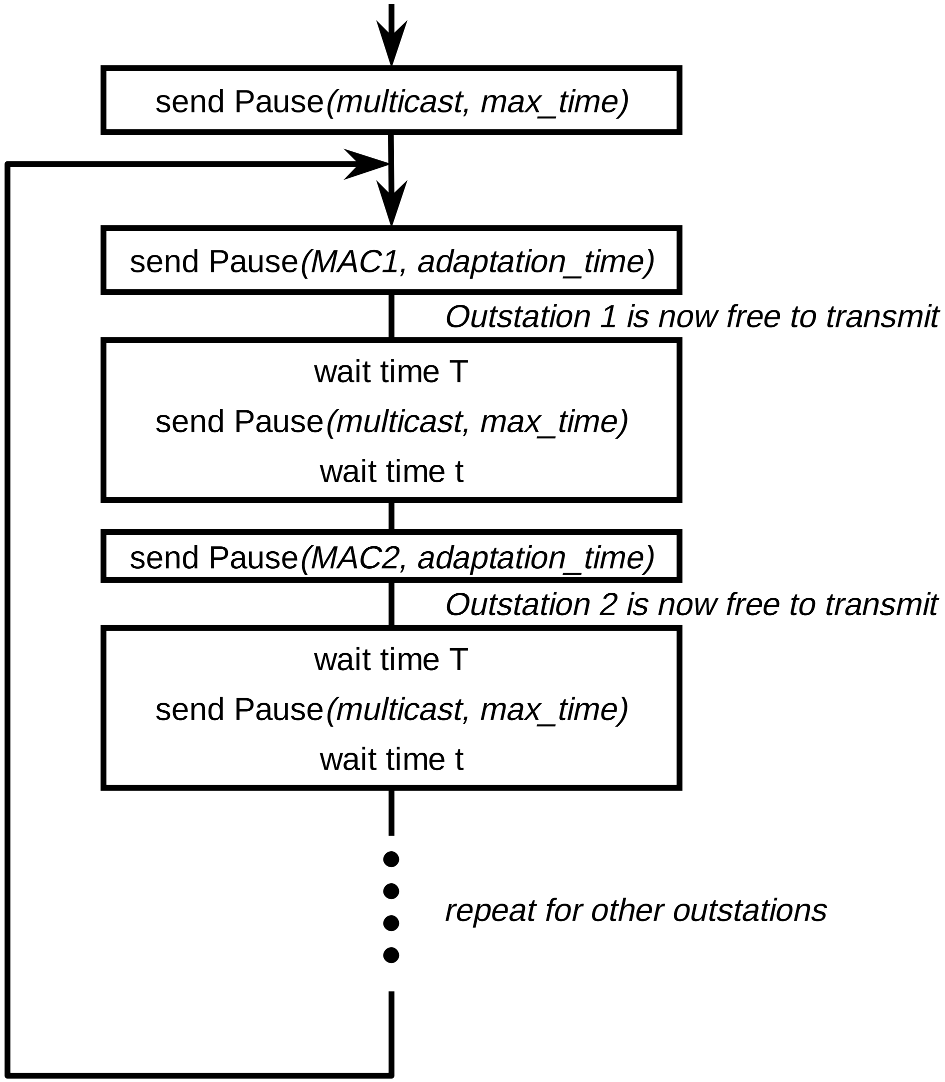
Review of Pause Facility: 1
(See 802.3 Standard, Clause 31, Annex 31B)

- IEEE 802.3 includes a mechanism to hold off the emission of packets from a node by sending the node a ‘Pause Command’
- Pause Command specifies length of time to interrupt transmission in “Pause Quanta” (multiples of 512 nsec for Gigabit Ethernet)
- MAC finishes sending any packet that has already started, but must not start transmitting any new packets after receiving a Pause Command until the pause time expires
- A new Pause Command overwrites the a previous command. The newly specified pause time can be zero, effectively clearing the previous pause

Review of Pause Facility: 2

- **Pause packets are minimum fixed-length packets (64 bytes, approx 500 nsec), inserted, in-band, between data packets**
- **Nodes implementing the pause facility must respond to commands sent to both a well known multicast destination address (multicast pause) and the node's own MAC address (directed pause)**
- **The well-known multicast address does not pass through 802.1D bridges (ref: 802.1D, Table 7-9)**

GEPON outstation control proposal



<u>Notes</u>:

T nominal length of timeslot for each outstation

t overlap time – allows for completion of packet in progress and differential propagation delay

Total polling time is n * (T+t), where n= number of outstations

max_time – calls up maximum delay (~32ms)

adaptation_time – allows outstation laser to stabilise and head end to adapt to new transmission conditions before data transfer starts

multicast – well known multicast address for control packets

MAC1, MAC2, etc – individual station MAC addresses

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Plug and play – requirements

- Bring up an already populated system from cold
- Connect new subscriber(s) to a system already carrying traffic
- Avoid disruption to existing subscribers
- No manual intervention to establish data connectivity
- Additional steps may be needed to generate billing information, customer service profile, etc. but this is outside the scope of 802.3

Plug and play – methodology

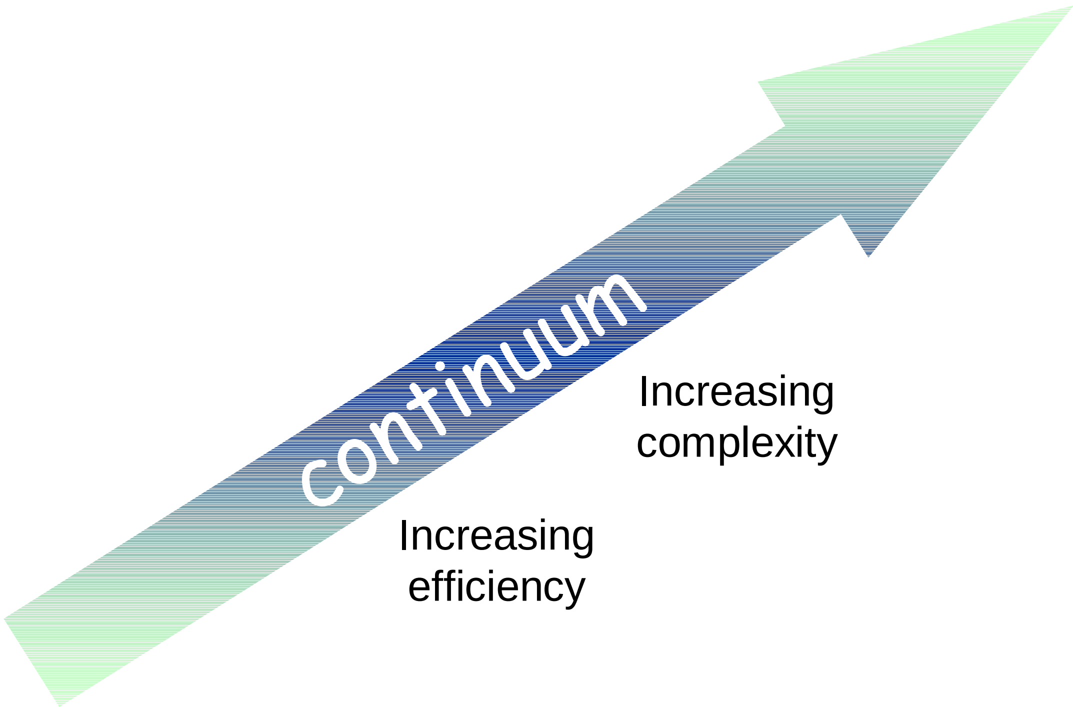
- **Allocate an upstream timeslot for each subscriber**
- **Allocate an extra timeslot for attaching new subscribers**
  - Need not occur in each polling cycle
  - Use the same slot for ranging, if present
- **Use an ALOHA-type protocol to allow multiple new subscribers to attach simultaneously**
  - Each subscriber applies in the attachment slot
  - Application includes the unique address (MAC) of the subscriber
  - Head end sends an acknowledgement containing the subscriber's unique address
  - If a collision occurs, all unsuccessful subscribers timeout, back off and re-apply
- **Once new subscriber is known, range measurement can be performed (if required)**
- **New subscriber is then included in normal polling cycle**

Ranging background
(also known as marshalling)

- **Takes account of differing propagation delays between headend and subscriber connection points**
- **Requires two main functional steps**
  - Measure round trip delays to each subscriber
  - Compensate for delays to allow gaps between transmissions to be closed up without causing collisions
- **Compensation can be performed in two ways**
  - Either: change timing of ‘grant’ signals from head end
  - Or: add subscriber buffers to delay signal by appropriate amount
- **May re-measure periodically to allow for drift**
- **Ranging increases complexity but improves efficiency**

Ranging and efficiency

Fixed size
Sub-frame
(i.e. ATM Cells)
ranging
(FSAN)



Increasing
complexity

Increasing
efficiency

No ranging –
just leave big
gaps for
guard band

Fibre network

- **802.3 has already addressed fibre performance at gigabit rates**
- **Significant work on PON configurations has already been done by FSAN**
  - Higher bit rates required for Gigabit Ethernet PONs can build on this work
- **Performance of fibre, splitters, connectors and splices is well understood**
- **Details of the optical power budget are for debate, but overall totals will be practically achievable, certainly for 16 way and possibly for 32 way splits (@ 10 km reach)**
- **Limiting splitter configuration options implies lower electro-optical component costs**
  - E.g. All subscriber nodes connected at the same level of split

Optical devices

- **FSAN proposes 1490 nm downstream and 1310 nm upstream**
  – Leaves 1550 nm band free for WDM overlays
- **For cost reasons subscriber node must adopt an uncooled laser**
  – Fibre loss calculations must allow for laser wavelength drift
- **Subscriber node laser must be disabled except during active time slot**
  – Laser operation must stabilise within acceptable time window (target 1 microsec)
- **Headend receiver must adapt rapidly to differing optical signal levels from different subscriber nodes**
  – Target response time 2 microsec
  – Dynamic range requirement is minimised by connecting all subscribers at same split ratio
- **Several optical component manufacturers have confirmed that they can produce devices following acceptable cost curves**

Management

- **Network operators will require management facilities**
- **For FTTH, subscriber unit must be a low cost device**
- **May not include IP layer so management must be in Layer 2**

Therefore:

- **Management system for subscriber unit should be lightweight**
- **Desirable features include**
  - Gathering link statistics
  - Enable / disable logic loopbacks and/or echo
  - Put subscriber unit in / out of service (outside scope of 802.3)
  - Remote control of subscriber configuration (if appropriate)

Summary

- There are no insurmountable technical barriers to achieving a Gigabit Ethernet PON
- In many instances we can base solutions on work done elsewhere
- Pragmatic choices during standards development will improve costs and time to market