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TITLE: G.fast: Discontinuous Mode Power Saving

ABSTRACT

Contribution 2012-05-4A-030 proposes a discontinuous mode power saving (DMPS) method for G.fast. It describes how DMPS can significantly reduce the power consumption of a G.fast transceiver when traffic is in a low level. The power saving due to DMPS in G.fast will be significantly more than that due to traditional methods used in ADSL2. Different schemes are proposed to implement DMPS for G.fast. This contribution is a revised version of 2012-05-4A-030 and is made to be consistent with the relevant agreements achieved at the last meeting.

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1. Introduction

In G.fast, when user traffic is lower than the channel capacity, the line rate can be reduced to save power.

The short loops used in G.fast will require low PSD level and low transmit power that will mean less power consumption on line driver (LD). However, wide bandwidth and high sampling rate used in analog front-end (AFE) and digital front-end (DFE) will demand higher power consumption. Unlike in ADSL2/2plus and VDSL2 where LD power consumption is higher than those of AFE and DFE, in G.fast the reverse is true. In other words, it is expected that DFE and AFE each will consume more power than LD. In this case, unlike ADSL2, for example, simply reducing transmit PSD will not save significant amount of power. The discontinuous mode of power saving is a much better choice for G.fast to save power when user traffic is low. Contributions 11BM-035 [1] and 2012-05-4A-030 [2] proposed using discontinuous mode power saving for G.fast.

Time-division duplexing (TDD) has been adopted as the duplexing method for G.fast. The discontinuity inherent in TDD makes the implementation of discontinuous mode power saving (DMPS) more practically feasible in G.fast.

In the DMPS method, when user traffic is lower than channel capacity, the entire transmission and reception path can be turned off during some DMT symbols within a TDD frame to save power on DFE, AFE, and LD.

Because vectoring will be used in P2P G.fast, the non-stationary crosstalk resulting from discontinuous mode can be managed.

This contribution is a revised version of 2012-05-4A-030 [2] and is made to be consistent with the relevant agreements achieved at the last meeting [3].

2. Why Discontinuous Mode Power Saving?

In this section we summarize the reasons that DMPS is the best choice to save power in G.fast.

1) Each of the AFE and DFE power consumptions is higher than the power consumption of LD. Therefore, simply lowering transmit PSD but transmitting all the time will not save significant power overall.

2) In the discontinuous mode power saving (DMPS) method, the entire transmission and reception path can be turned off during some DMT symbols within a TDD frame to save power on DFE, AFE, and LD.

3) G.fast will use TDD method. The discontinuity inherent in TDD makes the implementation of DMPS more practically feasible in G.fast.

4) Because it was agreed (issue 1.4/March 2, 2012) that G.fast will support vectoring and FEXT cancellation with P2P distribution, the non-stationary crosstalk generated by DMPS to other lines can be managed.

3. Discontinuous Mode Power Saving Method for G.fast

When user traffic in showtime on a line becomes lower than its achievable data rate, the number of transmitted DMT/OFDM symbols within a TDD frame can be reduced. This allows the entire transmission and reception path to be turned off during some DMT/OFDM symbol periods to save power in DFE, AFE, and LD.

When user traffic in showtime on a line increases, the number of transmitted DMT/OFDM symbols within a TDD frame is increased until all the DMT/OFDM symbol slots within a TDD frame are used for transmission.

Given a traffic volume in bits per second, the minimum number of active DMT/OFDM symbols in a TDD frame is given by

$$\text{number of active symbols} = \left\lceil \frac{\text{traffic volume} \times \dfrac{T_{\text{total}}}{\text{symbol rate}}}{\text{number of bits per symbol}} \right\rceil$$

where $\lceil g \rceil$ is the ceiling function and T_{total} is the total length of a TDD frame in number of DMT/OFDM symbols.

The on-line reconfiguration of the DMT/OFDM symbol slots within a TDD frame is performed by the pair of transceivers on a per-line basis to adapt to the user traffic. In particular, the number of active DMT/OFDM symbol slots within a TDD frame can be configured to be proportional to the volume of user traffic. Such a reconfiguration can be performed in the downstream direction only, in the upstream direction only, or in both directions. It does not change the asymmetry ratio between the nominal downstream data rate and nominal upstream data rate of the line. It does not modify the configuration of the DMT/OFDM symbol (e.g., the number of bits per symbol), either.

A possible procedure for a seamless on-line reconfiguration of the DMT/OFDM symbol slots within a TDD frame is described as follows. First, the message for changing the number of transmitted DMT/OFDM symbols within a TDD frame is transmitted from the FTU-O to the FTU-

R during a sync symbol, for example. The message contains the information of the new set of active DMT/OFDM symbols within a TDD frame; i.e., a mapping function. After receiving the message, the FTU-R sends an acknowledgement message to the FTU-O. Both the FTU-O and the FTU-R switch simultaneously to the new set of active DMT/OFDM symbol slots starting from a pre-defined TDD frame.

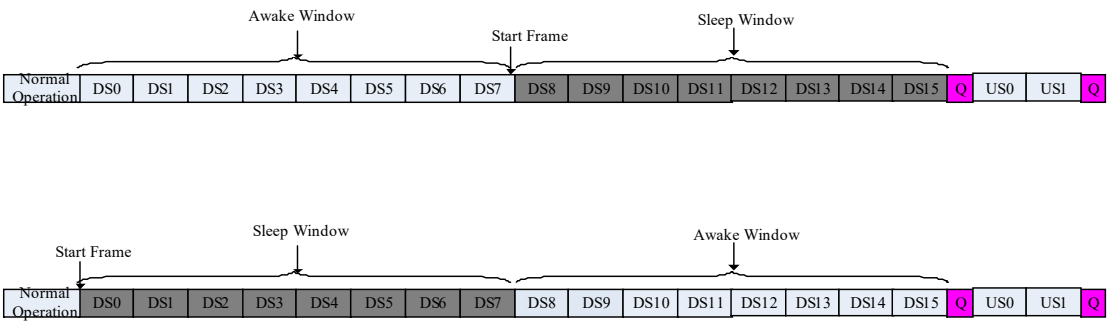
Another possible procedure is reducing the number of active symbols on a TDD frame basis. This can be done by inserting information in a previous TDD frame about the number of active transmit symbols at subsequent TDD frames.

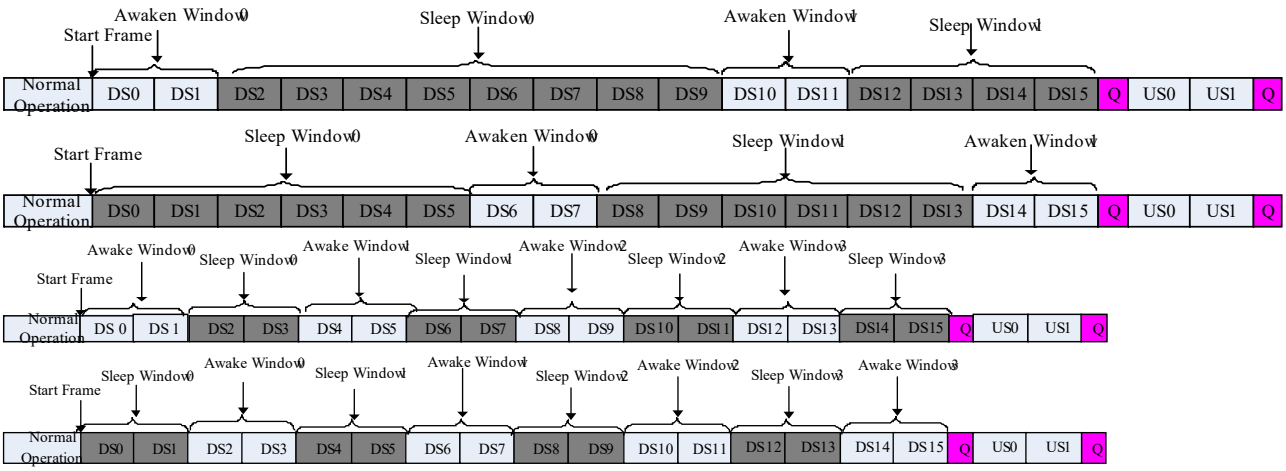
Depending on the TDD framing format and size selected for G.fast, different methods maybe used to turn off DMT symbols to save power.

The following figure shows a typical TDD frame with 16 DS and 2 US DMT symbol positions with 2 Q (Quiet) intervals (i.e., guard time periods) inserted in between:

Different methods may be used to implement DMPS in TDD G.fast. Here we describe one method. First we define Awake and Sleep windows. The length of an Awake window is proportional to the line rate and can change at TDD frame level or Superframe level by communicating this information to the receiver.

The last or first few consecutive symbol positions of a frame are selected to be in the Sleep Window, as shown in the following two figures, respectively. A potential problem with this method is that the FTU-R may lose sync if the length of a Sleep window is too long. However, it does have the minimum number of turn-on/turn-off switches of the DFE/AFE/LD per TDD frame.





Note that lines within a DP group can have different Awake Window lengths.

Having a different Awake Window length for each line will not cause a problem with vectoring as long as the vector engine is aware of any overlap among Sleep and Awake windows of different lines.

Different levels of DMPS can be defined depending on tolerable latency levels. The above method is for the case of low-latency (e.g., under 1ms). For example, if more latency can be allowed, the entire frame or even entire Superframe may be turned off to save more power. The following three cases can be defined:

- Low latency DMPS (<1ms) low power saving (up to about X1 dB)
  - Variable active symbol positions down to 2 symbol positions per TDD frame (as shown in the above figures)
- Medium latency DMPS (<Y1 ms) medium power saving (up to about X2 dB)
  - 2 active symbol positions every 2, 4, or 8 TDD frames
  - Recovery time to full rate and low latency < 6ms
- High latency DMPS (<Y2 ms) high power saving (up to about X3 dB)
  - 2 active symbol positions every Z superframes
  - Fast timing realignment
  - Needed for keeping alive down to life-line standby
  - Recovery time can be up to 100ms or more as additional delay to dial tone / ring tone

Y1, Y2 and Z values are TBD. X1 < X2 < X3 will be implementation dependent but they are expected to be at least 8, 15, and 30, respectively.

4. Management of Resulting Non-Stationary Crosstalk

When a certain DMT/OFDM symbol within a TDD frame on a line is turned off during the next TDD frame or vice versa, this creates non-stationary crosstalk into other lines connected to the same access node. Two schemes can be applied to mitigate the impact of the non-stationary crosstalk resulting from the discontinuous transmission mode.

4.1 Node Management

When a line is going to turn off some of the DMT/OFDM symbols during the next TDD frame, it sends this information to the control entity at the access node. The control entity forwards this information to the victim lines so that their transceivers do not increase their bit loadings to adapt to the temporarily improved crosstalk condition due to that some DMT/OFDM symbols are turned off on the disturbing line. This method avoids the potential stability problem on the victim lines when the same DMT/OFDM symbols on the disturbing line are turned on in the future.

Alternatively, the SNR maybe measured and monitored only on the DMT symbols that are always awake and never sleep for the entire distribution point.

4.2 Crosstalk Mitigation

If vectoring is implemented at the access node to cancel crosstalk, the on and off behaviours of the DMT/OFDM symbols on a line have the same impact on victim lines as the joining of a new line and the orderly leaving of a vectored line, respectively, provided that the vector control entity possesses the knowledge of the on and off behaviours of the DMT/OFDM symbols. Therefore, existing vectoring mechanisms dealing with the problems of joining of a new line and the orderly leaving of a vectored line can be exploited to effectively mitigate the aforementioned non-stationary crosstalk resulting from the discontinuous transmission mode.

5. Summary and Proposal

This contribution lists the reasons why DMPS is the right method to save power in G.fast and proposes different schemes to implement it.

This contribution should be presented under the G.fast project.

It is proposed that the following open item on the latest G.fast issues list [3] be agreed:

6.4.1	Open 20-June-11	Should G.fast provide low power modes based on discontinuous operation, where the AFE and DSP are powered down regularly on a short time scale maintaining some throughput and latency while saving significant power?	11BM-035, 2012-05-4A-030, 2012-05-4A-040

It is proposed that the following open item on the latest G.fast issues list [3] be agreed:

6.4.1.5	Open	Should G.fast define different levels of low power modes based on discontinuous operation as a function of maximum latency and recovery time?	2012-05-4A-030, 2012-06-4A-040

It is proposed that the following new item be added to the G.fast issues list:

6.4.1.x	Open	Should discontinuous operations be defined on a per TDD frame basis or on a per Superframe basis?	2012-06-4A-040

References

[1] BT, "*G.fast: Discontinuous Operation*", ITU-T SG15 Q4 contribution 11BM-035, June 2011.

[2] Huawei Technologies, "*G.fast: Discontinuous Mode Power Saving*", ITU-T SG15 Q4A contribution 2012-05-4A-030, May, 2012.

[3] Editor for G.fast, "*Updated Issues List for G.fast*", ITU-T SG15 Q4A contribution 2012-05-4A-U20R1, May, 2012.