White Paper

Using FPGA-Based Channel Bonding for HDTV Over DSL

Abstract

This white paper examines the market opportunities for channel bonding technology and the threat from fiber-based networks and protocol details of the channel bonding process, as well as describing the architecture of a DSLAM card with bonding. It closes with a listing of why FPGAs, such as Altera® Cyclone® III devices, are the optimum choice for implementing this type of application.

Introduction

On an almost daily basis, new video or voice applications push the bandwidth requirements for DSL networks, while telecom carriers in the U.S. and worldwide are targeting delivery of digital and high-definition television (HDTV) to consumers. To achieve delivery of such services without deploying new fiber everywhere, carriers must leverage existing copper deployments already in the ground.

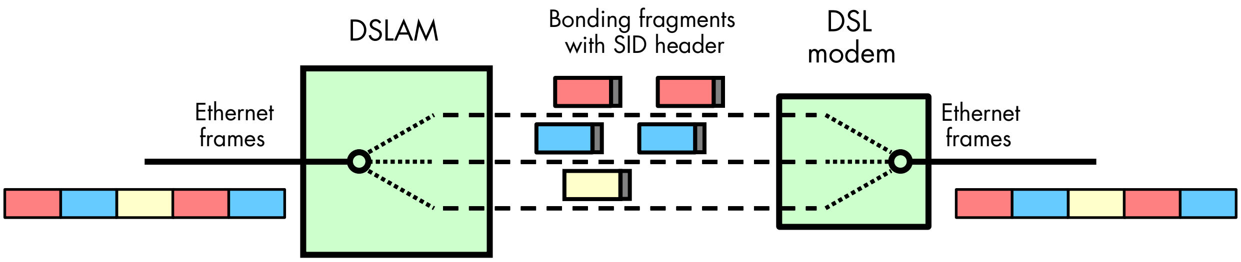
Most DSL lines offer enough capacity for delivering standard-definition television (SDTV). Most programs are available from streaming servers at bitrates of about 750 kbps, with some programs providing a 1.5 Mbps bitrate. However, to allow high-quality HDTV streaming and multiple channels simultaneously, a home must have a bandwidth of at least 16 Mbps. Although newer DSL generations of ADSL2 and VDSL can offer these speeds, they cannot offer high speed over a sufficiently longer distance on a typical DSL line. Therefore, HDTV programs can be delivered only to households close to the DSLAM. Those located further away can only receive lower quality SDTV programming.

To ensure that DSL remains the preferred choice for end users, service providers are looking for new ways to improve the performance of DSL networks. While VDSL and ADSL2 provide better performance, the distance limitations are difficult to overcome. Another scenario is to bring the DSLAMs closer to the end users, but the costs involved with installing new equipment in the network are often prohibitive.

Channel Bonding in DSLAMs and DSL Modems

DSL channel bonding provides the ideal mix of features: higher bandwidth to all users and the ability to extend the distance that can be reached at a certain bandwidth. Instead of using a single copper pair, DSL bonding distributes traffic over a bundle of copper pairs. To achieve an effective bandwidth of 12 Mbps, three DSL lines of 4 Mbps are bundled, with a channel bonding processor at each end of the lines. In most copper networks, subscribers are already connected via several wires, so no new cables need be installed to provide channel bonding service, as shown in Figure 1.

Figure 1. Overview of DSL Bonding: Packet Fragments Distributed Over DSL Lines



Another interesting application for DSL bonding is in mobile networks, where the access interface connecting a basestation to a switching center uses a DSL line. With the continuous growth of data traffic over wireless networks, more capacity is needed in the backhaul network. A straightforward scenario is to multiply the DSL network capacity with channel bonding.

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DSL bonding processing is implemented in a special multi-channel bonding card in the DSLAM on the network side, while a similar processing step is performed in a dedicated DSL modem on the subscriber side. It could be argued that bonding is not needed as a special algorithm; instead, why not use several DSL lines in parallel to increase end-to-end bandwidth? This scenario is sometimes used by small offices that require a back-up line for Internet access, but each DSL modem line needs a separate Ethernet interface on the office router or network switch. Furthermore, the configuration of the routing tables is cumbersome and requires detailed knowledge of IP routing protocols to achieve good load balancing among the lines. While this setup may suit some business applications, it is too complex in most cases and not acceptable for residential applications. The desired solution must be transparent to the end user and should be as easy to configure as a normal single-line DSL modem.

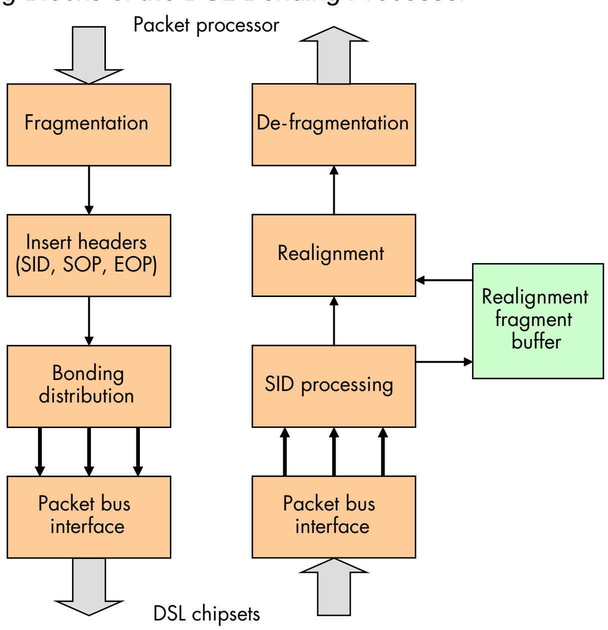
To allow an optimum fit with the specific application requirements in DSL networks, a dedicated channel bonding scheme is defined. The software complexity and management overhead of DSL channel bonding has been kept low, in comparison to Inverse Multiplexing for ATM (IMA). Other critical factors include deterministic and low transport latency that compare favorably to the Link Aggregation Protocol used in IEEE802.3 Ethernet and the Multi-Link Point to Point Protocol (ML-PPP) of the IETF.

There are two main implementation variants of DSL channel bonding: ATM cell based, used primarily for ADSL and derivatives, and Ethernet fragment bonding for VDSL lines. The Ethernet operation mode has common functionality with Ethernet in the First Mile (EFM) and is also known as Packet Transfer Mode (PTM), to indicate its similarity with Asynchronous Transfer Mode (ATM).

DSL Channel Bonding Protocols

The ATM and PTM DSL channel bonding modes are standardized by the ITU-T in recommendations G.998.1 and G.998.2 respectively. In both channel-bonding schemes, the end-user packets are split in small cells of 53 bytes (ATM) or small fragments of up to 512 bytes (PTM). When bonding is activated on a DSL bundle, these cells are distributed evenly over the individual DSL lines. At the receiving end, the cells are realigned to recover from differential delays in the transmission path and subsequently the cells are reassembled into packets. To support the realignment and reassembly processing, each cell is prefixed with a header that contains a sequence identifier (SID), a start of packet (SOP) indicator and an end of packet (EOP) indicator. The receive side uses the SID to rearrange the incoming cells in the correct order, while the SOP and EOP indications are used to reassemble the stream of cells into complete data packets, as shown in Figure 2.

Figure 2. Functional Building Blocks of the DSL Bonding Processor



There is no fixed upper limit to the number of channels that are bundled in a bonding group, but typically only two or four lines are available to an end customer. The protocol can be used on DSL lines with different capacities. The realignment process at the receive side can handle unequal delays incurred on the individual DSL lines. Channel bonding operates on both directions of the DSL line, thus increasing both downstream and upstream bandwidth.

The bonding protocol is also very efficient as the protocol overhead is limited to a 16-bit header in PTM mode, which is about a one percent capacity reduction. ATM-based channel bonding has even less protocol overhead, as it uses a portion of the already present ATM cell header fields to transport the SID.

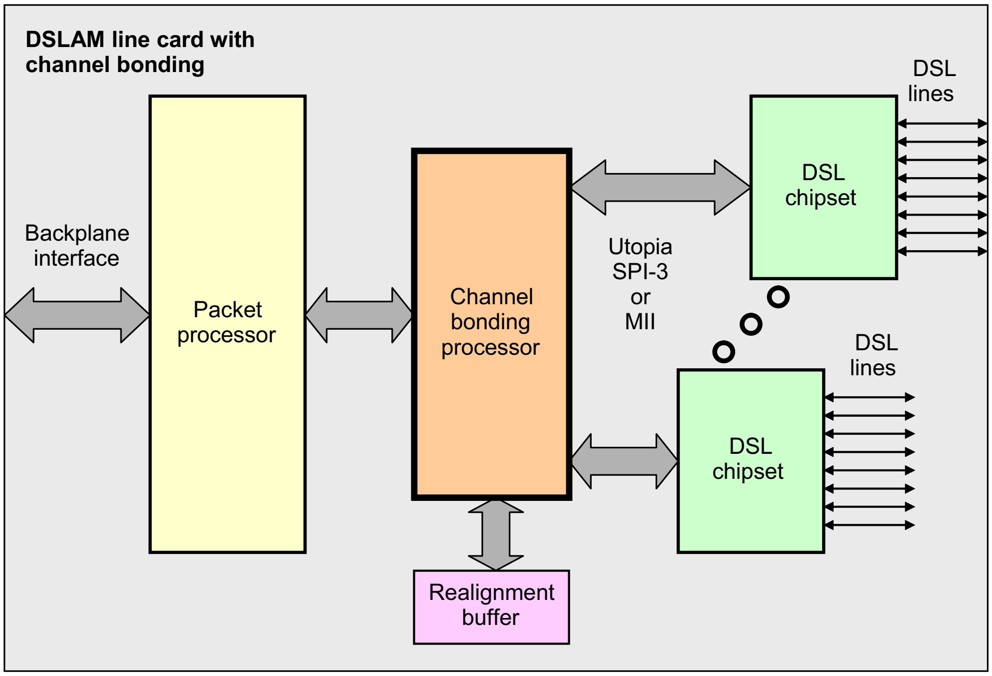
There are, however, a few quirks in the PTM protocol that demand a dual processing step. The data packet first is divided into fragments, each with a length between 64 and 512 bytes. These fragments are distributed over the members of the channel bonding group. Subsequently these fragments are split in cells of 64 bytes, which are transported over the DSL line.

DSLAM Architecture

The generic architecture of a DSLAM line card consists of a packet processor and a set of DSL line chipsets. The data transport is carried out via a standard packet bus such as Utopia-2, or SPI-3 Ethernet interfaces such as MII or SMII are used. The DSL bonding feature sits functionally between the higher layer packet processing and the DSL line processing, and some DSL device vendors provide DSL channel bonding as part of the data processing engine. However, the channels that are part of the bonding group must reside on the same device. This is a severe limitation, since most chipsets only handle eight DSL lines, while a typical DSLAM line card supports a much higher number of lines.

The installation and service turn-up of a new channel bonding group must be straightforward and it should be possible to create a new bonding group out of any free lines on the DSL card. This is achieved by placing a bonding processor between the packet processor and the DSL chipsets, so DSL line bonding groups can now be created that span multiple DSL chipsets. A possible configuration of a DSLAM line card is depicted in Figure 3.

Figure 3. Typical Application of the DSL Channel Bonding Processor on a DSLAM Line Card



Implementation on FPGAs

Altera Cyclone III FPGAs are the ideal match for implementing DSL channel bonding, especially on high-density, multi-channel line cards. By adding FPGAs for channel bonding, the packet processor is relieved from this additional processing, and the intermediate FPGA can provide other functionality required on the line card. As an example, there are many types of packet buses that can be supported, such as Utopia, SPI-3, and Ethernet-type bus interfaces on both packet processors and DSL chipsets. These buses can be implemented easily with FPGAs. In addition, FPGAs can act as bus converters between incompatible devices, such as connecting an Ethernet-based DSL chipset to the bus interface on a packet processor.

Due to the implicit flexibility of FPGAs, common product issues, such as rapid market introduction of a product where not all the details of a new standard are finalized, as well as vendors that may have different interpretations of these standards, are easily managed. The channel bonding FPGA can assist with mitigating small deficiencies found in the packet processor or DSL chipsets.

The processing functions involved with ATM and Ethernet-based channel bonding are different and can be supported by dedicated FPGA loads, depending on the target application or market requirements. An FPGA allows a smooth transition from one DSL chipset to another, with customer-specific logic or proprietary interfaces implemented in the same device. All functionality of the DSL channel bonding protocol can be integrated in a single FPGA: the bus interfaces, the data processing engines, and the protocol state machines. Altera Cyclone III FPGAs have sufficient resources to implement a cost-effective and flexible channel bonding processor.

Summary

Delivering IPTV services profitably to consumers requires carriers to leverage existing copper deployments. DSL channel bonding technology allows them to support HDTV and high-speed Internet access, even for subscribers with a large loop length. The bandwidth and distance requirements are met by bonding two or more copper channels in a bundle. These DSL channel bonding protocols can be easily implemented in FPGAs, such as Altera’s Cyclone III devices, that offer flexibility by supporting various bus interface options and other processing functionality on a single chip.

Further Information

- AimValley BV:
  www.aimvalley.com
- Altera’s Access Packet Processing Solutions:
  www.altera.com/end-markets/wireline/applications/access-flow/wil-access-flow.html
- ITU-T recommendation G.998.1:
  www.itu.int/rec/T-REC-G.998.1/en
- ITU-T recommendation G.998.2
  www.itu.int/rec/T-REC-G.998.2/en

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101 Innovation Drive
San Jose, CA 95134
www.altera.com