

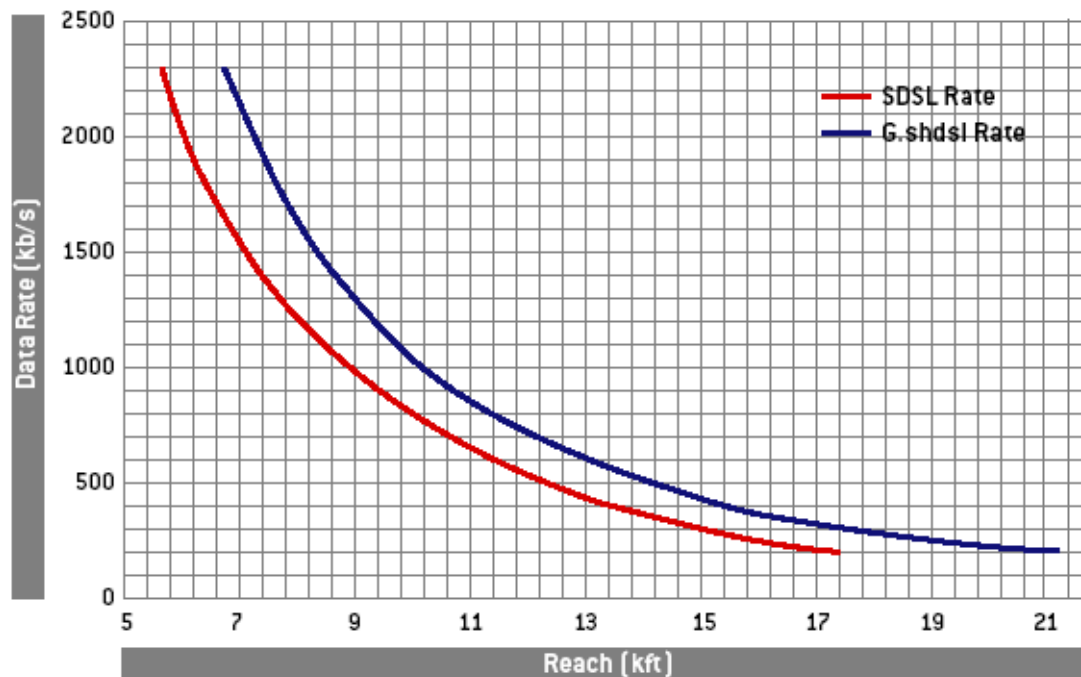
Extending the Reach and Rate of Symmetric DSL Service

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Introduction

Based on initial deployment and lab trials, it has become clear that G.SHDSL (subsequently referred to as SHDSL in this document) is a great technology that is more than capable of offering a business class symmetrical service. SHDSL is rate adaptive and selective in nature, which allows carriers the flexibility to offer different flavors of symmetrical DSL services with different speeds (64Kbps to 2.3Mbps) on the same copper pair. This is something that no other standardized DSL technology is capable of doing. SHDSL also delivers the best rate versus reach characteristics. As shown in Figure 1, SHDSL performs much better than SDSL, even under the worst operating conditions. SHDSL also has the best spectral compatibility and the best impairment tolerance of any other symmetrical DSL service.



This graph was generated using worst-case noise scenarios. Performance of G.shdsl will be greater than shown in 99% of loop applications.

Figure 1: Comparison of rate versus reach for SDSL and SHDSL

In addition to all the advantages mentioned above, the SHDSL standard also allows for the bonding of 2 SHDSL links (4 wire SHDSL) and the introduction of SHDSL repeaters both of which help improve rate versus reach characteristics. Four SHDSL pairs could also be bound using standard IMA to further extend the rate and reach. Both the repeater and multi-pair options will allow for an:

- Increased serving area for any given service level or an
- Increase in maximum service level at any distance from the central office.

A complete description of each solution including the pros and cons are listed below.

Basic Methods of Extending Reach and Rate

Rate and reach can be extended by either increasing the number of SHDSL links to a customer or by using an SHDSL repeater.

The use of a multi-pair SHDSL solution has many advantages, which include:

- The ability to increase the available bandwidth at a given distance from the central office by up to four times, thus significantly increasing the service level offered to customers.
- The ability to increase serving area by up to 100% at any given bandwidth level by utilizing some of the bandwidth increase to extend the reach.
- Greatly extending rate and reach without the addition of any outside plant equipment, thus reducing the complexity and the cost of deployment.

Repeaters also have advantages, including:

- The ability to increase reach without sacrificing bandwidth!
- The ability to offer a ubiquitous symmetrical business class DSL service.

The following sections outline the highlights of the various multi-pair and repeater solutions.

4-wire Method Highlights

Listed below are several highlights of 4-wire SHDSL:

- Uses standard 4-wire implementation of SHDSL to deliver bandwidth up to 4.6Mbps.
- Offers the cheapest alternative to increase rate and reach.
- Allows for twice the bandwidth at any given distance compared with 2-wire SHDSL or an approximate 40% increase in reach at any given bandwidth level.
- It is possible to provision a 4-wire CPE to operate in 2-wire mode or 4-wire mode.
- A current limitation of 4-wire is that if one of the links drops all service is lost.

IMA Highlights

Listed below are highlights of SHDSL IMA.

- Uses ATM standard IMA to bond up to 4 SHDSL pairs resulting in an aggregate bandwidth of up to 9.2 Mbps.
- Allows for four times the bandwidth at any given distance compared with 2-wire SHDSL.
- Facilitates an approximate 100% increase in reach at any given bandwidth level compared with 2-wire SHDSL.
- This solution is more robust than the 4-wire method due to IMA's ability to survive link drops. As long as one of the links is up service will continue.
- The GoWide 9.2 CPE can be deployed with as few as one SHDSL pair and as many as four, allowing for future growth if initial capacity is not used.

Repeating Highlights

Listed below are highlights of repeated SHDSL.

- Uses ITU-T standard for repeating SHDSL.
- Allows for a several times increase in distance without sacrificing bandwidth by connecting up to 8 SHDSL repeaters in series.

The following sections give a detailed description of each of the solutions mentioned above.

4-wire

Technology

4-Wire SHDSL is a mode of SHDSL operation covered under the SHDSL standard (ITU-T G.991.2). The implementation results in two SHDSL links being bonded to appear as one physical entity. Traffic is interleaved equally between each of the SHDSL links on the transmitting end and then reassembled at the receiving end. Figure 2 below illustrates the process. When operating in 4-wire mode, both SHDSL links must be synchronized to operate at the same line rate. While in 4-wire mode, if one of the links should fail, the combined link will fail and service will be lost.

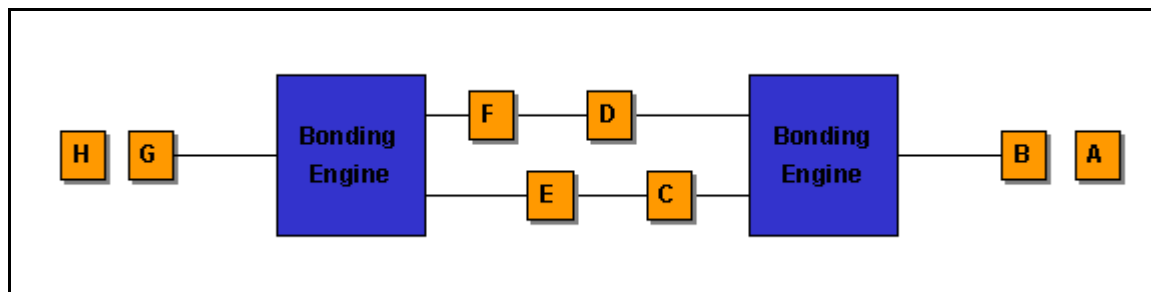


Figure 2: 4-Wire SHDSL Bonding

4-Wire SHDSL is capable of offering symmetric bandwidth between 128Kbps and 4.6Mbps at 128Kbps increments. Like the 2-wire version of SHDSL, 4-wire SHDSL is a purely digital implementation that uses a Trellis Coded Pulse Amplitude Modulation (TC PAM) based modulation scheme. TC PAM is particularly attractive for its friendly spectral characteristics (its narrow frequency band reduces the possibility of interference with other DSL technologies) and improved performance in the presence of interference.

The end result of using 4-wire SHDSL is that it allows for the deployment of service at rates equal to two times that of regular 2-wire SHDSL or at distances of up to 40% greater than that of 2-wire SHDSL. Figure 3 below illustrates the rate versus reach gains using 4-wire.

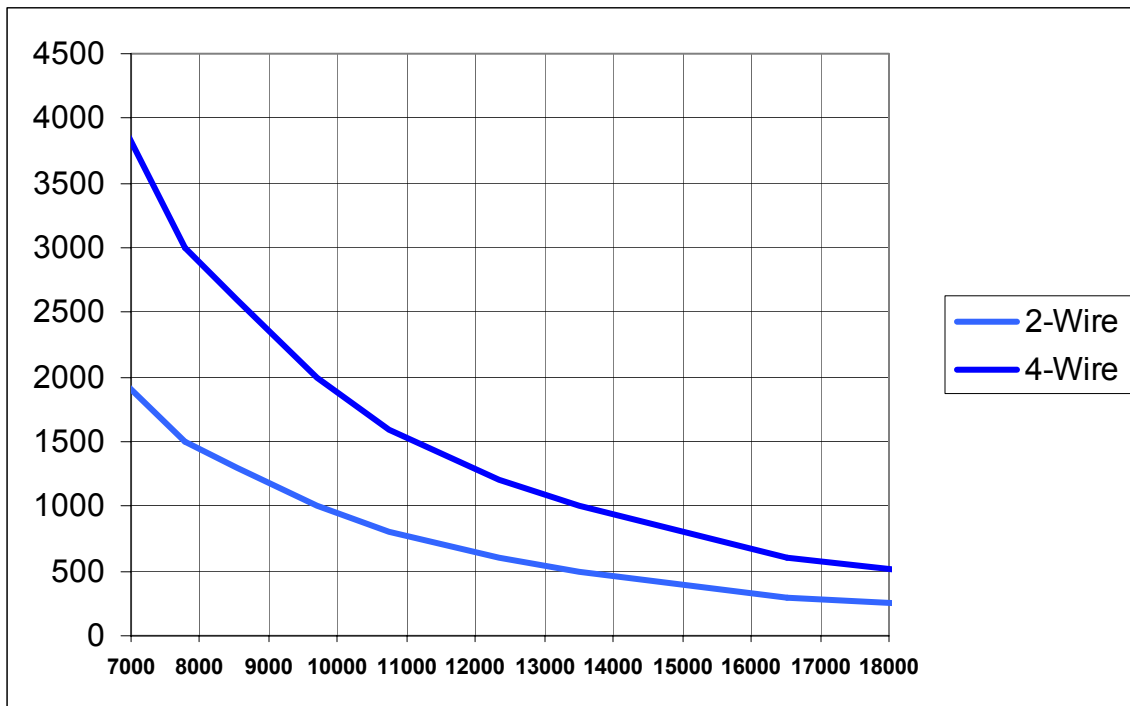


Figure 3: Rate versus Reach for two and 4-wire

Because a 4-wire SHDSL CPE is capable of working with one or two SHDSL links, it also offers the opportunity to start off with a low bandwidth service agreement and easily up sell further bandwidth when needed without changing out the CPE. Finally, although SHDSL 4-wire can be combined with the benefits of an SHDSL repeater to offer even greater rate versus reach, it is a great alternative to extending rate versus reach on its own.

Deployment Requirements

Figure 4 illustrates the generic requirements for a 4-wire SHDSL deployment. The main components of the deployment are a 4-wire SHDSL CPE, a DSLAM capable of supporting the 4-wire standard and the two copper pairs connecting the two. Although the SHDSL standard does not require ATM as the layer two protocol, most SHDSL deployed today uses ATM. It should also be noted that most 4-wire CPE could run in 4-wire mode (two pairs with total bandwidth of up to 4.6Mbps) or 2-wire mode (single pair with total bandwidth of up to 2.3Mbps).

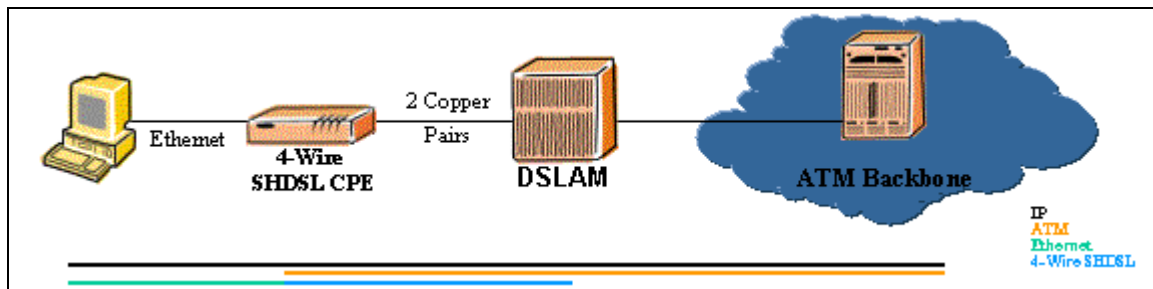


Figure 4 Generic 4-wire SHDSL system requirements

The DSLAM requires that SHDSL lines bound together for 4-wire operation must be adjacent to one another on the SHDSL line card. These requirements are a result of the fact that one 2-port SHDSL chip is used to provide the 4-wire service and each pair of wires used for the 4-wire service must be going to the same chip.

Product Descriptions

Symmetricon's GoWide 4.6 SHDSL CPE

Symmetricon's GoWide 4.6 is an integrated bridge, router, and gateway with 2-wire and 4-wire G.shdsl support for flexible DSL access. GoWide 4.6 has a four-port 10/100BaseT Ethernet switching hub allowing up to four PCs or Ethernet devices to be connected directly to GoWide 4.6 without the need for a separate hub.

Designed for businesses requiring high speed Internet or LAN-to-LAN access for mission critical applications, GoWide 4.6 uses next generation G.shdsl to deliver scalable bandwidth up to 4.6Mbps. This allows voice, video, and data convergence using high speed symmetric DSL Access above 2.3 Mbps beyond the coverage area serviced by traditional DSL or 2-wire G.shdsl.

Based on the worldwide G.shdsl (ITU-T G.991.2) standard, GoWide 4.6 provides businesses such advantages as unrivaled rate/reach and excellent tolerance to noise and bridged taps. All of these advantages will enable Service Providers to increase end user satisfaction and lower system cost.

GoWide 4.6 has been designed to interoperate with existing routers and firewalls, and to be installed on a company's existing network infrastructure, thus protecting an organization's initial capital outlay. GoWide 4.6 supports DHCP, DNS for easy LAN setup, and has built-in basic firewall and VPN support to provide new network installation with secure data on an always-on DSL connection. GoWide 4.6 also has ATM support with PPPoA, IPoA, RFC1483 and PPPoE.

GoWide 4.6 scales as network and bandwidth needs expand. Once installed, speeds up to 4.6 Mbps can be provisioned over the network without the need for additional expensive truck rolls. This also reduces capital costs and operating expenses through device consolidation. Integrated with an easy-to-use Web-based management system, GoWide 4.6 reduces maintenance and deployment costs with its remote management capability, configuration store/restore facility, and firmware download support. GoWide 4.6 offers auto-sense 10/100BaseT for automatic discovery of Ethernet speed and auto MDI/MDIX capability, allowing automatic detection and line pairs switching. This eliminates the need to configure port speed as well as the need for crossover cables.

Alcatel 7300 ASAM 4-wire Functionality

Alcatel's 7300 ASAM supports both ADSL and SHDSL technologies. The ASAM's SHDSL line cards, available in both 12 and 24 line variants, can be used to provide symmetric DSL services between 64Kbps and 2.3Mbps on a single copper pair.

The SHDSL line cards are capable of operating in either two-wire or four-wire mode. Defined in the SHDSL standard, four-wire mode uses two adjacent pairs on the SHDSL line card to provide between 128Kbps and 4.6Mbps bandwidth to the customer premises. The line cards also offer asymmetric PSD capabilities to address the market needs for higher performance symmetrical services.

As with ADSL, SHDSL traffic enters the 7300 ASAM at the network termination (NT) card, where it is placed on the IQ bus. The line card selects ATM cells from the bus and sends them downstream to CPE over a single twisted pair, two pairs (four-wire mode), or up to 8 lines via IMA. Cells in the upstream direction (from CPE) contend for access to the IQ bus with any other resident line termination cards based on QoS.

IMA

Technology

Unlike 4-Wire SHDSL, which is a mode of SHDSL operation covered under the SHDSL standard (ITU-T G.991.2), SHDSL with IMA is simply an implementation of SHDSL that takes advantage of another standard which is Inverse Multiplexing over ATM. The implementation results in up to four standard 2-wire SHDSL links being multiplexed together to form one virtual connection. Traffic is interleaved equally between each of the SHDSL links on the transmitting end and then reassembled at the receiving end. Figure 5 below illustrates the process. When operating in SHDSL IMA mode, all SHDSL links must be synchronized to operate at the same line rate.

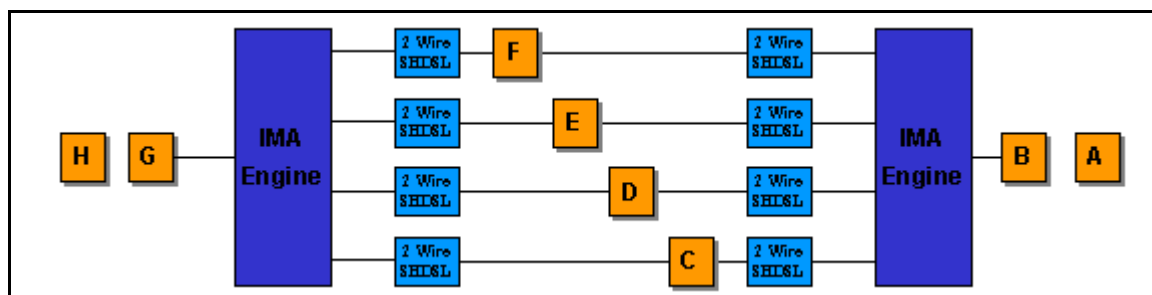


Figure 5 SHDSL IMA

One key advantage of IMA over 4-wire is that if one of the links should fail in IMA mode, the remaining links will continue to provide service. Similarly, as soon as a failed link re-establishes sync, it will automatically be added to the IMA group and immediately begin providing service.

SHDSL IMA is capable of offering symmetric bandwidth between 64Kbps and 9.2Mbps at 64Kbps increments. SHDSL IMA uses multiple 2-wire SHDSL links, each of which is a purely digital implementation that uses a Trellis Coded Pulse Amplitude Modulation (TC PAM) based modulation scheme. TC PAM is particularly attractive for its friendly spectral characteristics (its narrow frequency band reduces the possibility of interference with other DSL technologies) and improved performance in the presence of interference.

The end result of using SHDSL IMA is that it allows for the deployment of service at rates equal to four times that of regular 2-wire SHDSL or at distances of approximately twice that of 2-wire SHDSL. Figure 6 below illustrates the rate versus reach gains using 8-wire IMA over both 2-wire and 4-wire operation.

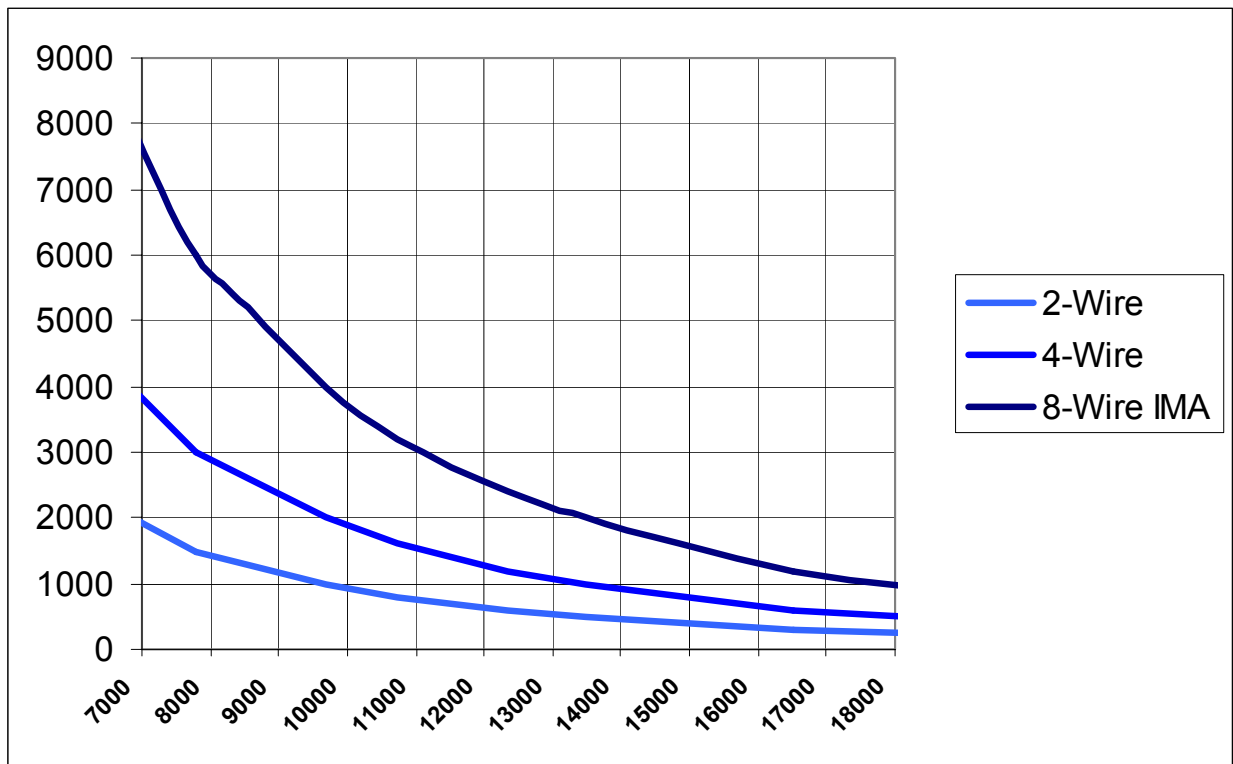


Figure 6: Rate versus Reach for 2-wire, 4-wire and 8-wire IMA

SHDSL IMA also adds another layer of reliability by allowing for continued service even if one or more of the links fail. Because SHDSL IMA is capable of working with one to four SHDSL links, it also offers the opportunity to start off with a low bandwidth service agreement and easily up sell further bandwidth when needed without changing out the CPE. Finally, although SHDSL IMA can be combined with the benefits of an SHDSL repeater to offer even greater rate versus reach, it is a great alternative to extending rate versus reach on its own.

Deployment Requirements

Figure 7 illustrates the generic requirements for an SHDSL IMA deployment. The main components of the deployment are an SHDSL IMA CPE, a DSLAM capable of supporting the SHDSL and IMA standards and the four copper pairs connecting the two. Both SHDSL and IMA protocols are point-to-point protocols supported only between the CPE and the DSLAM.

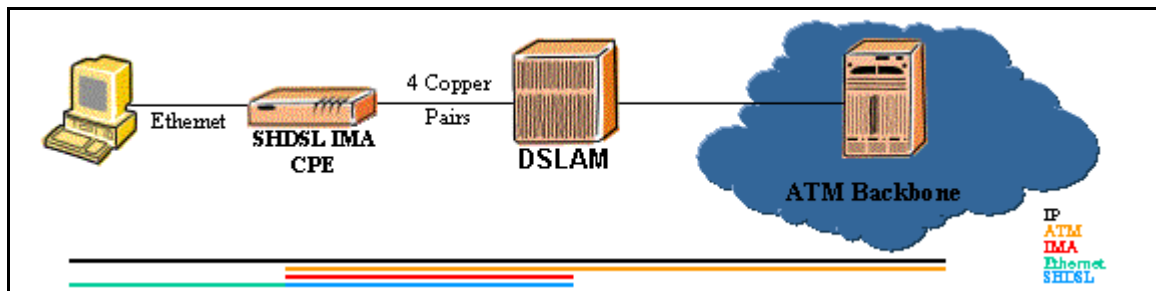


Figure 7 Generic SHDSL IMA system requirements

For SHDSL IMA configurations, lines 1 through 12 can only be grouped with lines 1 through 12. Likewise, lines 13-24 can only be grouped with lines 13--24. For instance, Lines 1, 2, 11 & 12 can be provisioned as an IMA group but lines 1, 2, 13 & 14 cannot be provisioned as part of the same IMA group based on this restriction.

Product Descriptions

Symmetricon's GoWide 9.2 SHDSL IMA CPE

Symmetricon's GoWide 9.2 is an integrated bridge, router, and gateway device with four G.shdsl ports for DSL access, and a four-port 10/100BaseT Ethernet switching hub allowing up to four PCs or devices to be connected directly to GoWide 9.2 without the need for a separate hub.

Based on the worldwide G.shdsl (ITU-T G.991.2) standard, GoWide 9.2 provides businesses such advantages as unrivaled rate/reach, excellent tolerance to noise, and bridged taps. All of these advantages will enable Service Providers to provide increased end user satisfaction at low system cost.

GoWide 9.2 has been designed to interoperate with existing routers and firewalls, and to be installed on a company's existing network infrastructure, thus protecting an organization's initial capital outlay. GoWide 9.2 supports DHCP, DNS for easy LAN setup, and has built in basic firewall and VPN support to provide new network installation with secure data on an always-on DSL connection.

GoWide 9.2 integrated Inverse Multiplexing over ATM technology enables high-speed symmetric DSL access at above 2.3 Mbps beyond the coverage area served by traditional DSL or two-wire and four-wire G.shdsl. GoWide 9.2 scales with network and bandwidth needs. GoWide 9.2 can be provisioned to operate with up to four G.shdsl ports. With four G.shdsl lines, speeds up to 9.2 Mbps can be provisioned over the network without the need for additional expensive truck rolls. This reduces capital costs and operating expenses through device consolidation.

Integrated with an easy-to-use Web-based management system, GoWide 9.2 reduces maintenance and deployment costs with its remote management capability, configuration store/restore facility, and firmware download support. GoWide 9.2 offers auto-sense 10/100BaseT for automatic discovery of Ethernet speed and auto MDI/MDIX capability, allowing automatic detection and line pairs switching. This eliminates the need to configure port speed as well as the need for crossover cables.

GoWide 9.2 design, manufacturing, and support are performed entirely by Symmetricon, a recognized leader in Network Synchronization and Timing. Symmetricon's manufacturing facilities are fully ISO 9001 certified and meet Telcordia GR-2981 CORE requirements. In addition, GoWide 9.2 is backed by Symmetricon's world class Customer Technical Assistance Center (CTAC) in the United States and the United Kingdom. The CTAC is capable of delivering 24/7/365 technical support coverage in over 80 countries throughout North America, South America, Europe, Asia, and Africa.

Alcatel 7300 ASAM IMA Functionality

In addition to both two-wire and four-wire SHDSL operation, Alcatel's 7300 ASAM can provide higher bandwidth symmetric services and extend reach using SHDSL IMA. The 7300 ASAM's SHDSL IMA can be used to bond up to eight lines together into a single virtual connection, offering between 64 Kbps and 9.2 Mbps of symmetric bandwidth to a single subscriber.

The 7300 ASAM currently supports IMA on the 24-line SHDSL card (SMLT-A). IMA functionality for the 12-line SHDSL card will be delivered as part of FG8. As IMA requires additional hardware on the line card, this functionality will be introduced in a new variant of the 12-line card.

Symmetricom's GoWide 18.4i SHDSL Multilink Access Concentrator and Aggregator

Introduction

GoWide™ 18.4i is a G.shdsl multilink access concentrator and aggregator. GoWide 18.4i concentrates up to eight remote 2.3 Mbps G.shdsl access devices for a total of 18.4 Mbps of combined throughput. Similarly, GoWide18.4i aggregates up to eight copper pairs to deliver fractional T3 service, and burstable bandwidth from 1.5 Mbps (one T1) up to 15 Mbps (ten T1s). New services – such as native Ethernet speeds – may also be provided by GoWide 18.4i.

GoWide 18.4i Technology

GoWide 18.4i uses up to eight G.shdsl circuits, to deliver burstable bandwidth of up to 15 Mbps for data applications plus T1 voice connections. GoWide 18.4i provides end-to-end service, operating with any G.shdsl, ATM based, digital subscriber line access multiplexer (DSLAM). GoWide 18.4i is an ideal solution for delivery of fractional T3 services (FT3) over copper pairs. Now, high-speed access services are made easy in those locations where fiber facilities are nonexistent or cost prohibitive.

Based on the worldwide G.shdsl standard (ITU-T G.991.2), GoWide 18.4i provides businesses such advantages as unrivaled rate and reach, excellent tolerance to noise, and robustness from physical link diversity. These advantages enable service providers to provide increased end user satisfaction at low system cost.

GoWide 18.4i's design operates with existing TDM based PBX telephone switches and ATM based routers. The result is quick migration of installed equipment to higher-speed service.

GoWide 18.4i's integrated bonding technology – or the ability to logically bundle multiple physical links into a single logical “fat pipe” - enables dynamic delivery of high-speed, business class, symmetric DSL access up to 15 Mbps for end-to-end voice and data connectivity across an ATM network. Additionally, the multilink technology allows facility redundancy which improves availability.

GoWide 18.4i scales as network and bandwidth needs expand. Once installed, aggregate data speeds may be provisioned from 1.5 Mbps (one T1) up to 15 Mbps (ten T1s) over the network without the need for additional expensive truck rolls. The result is reduced capital costs and operating expenses through device consolidation.

GoWide 18.4i's design, manufacturing, and support are performed entirely by Symmetricom, a recognized leader in mission critical network elements. Symmetricom's manufacturing facilities are ISO 9001 certified and meet Telcordia GR- 2981 CORE requirements. In addition, GoWide 18.4i is backed by Symmetricom's world-class Customer Technical Assistance Center (CTAC). CTAC delivers 24/7/365 technical support coverage in over 80 countries throughout North America, South America, Europe, Asia and Africa. Additional services such as installation and telephone support are available through Symmetricom's Global Services Division.

Key Features

- Delivers high-speed services over copper wires where previously fiber cables were required.
- G.shdsl International standard
- Serves up to eight remote G.shdsl access devices for up to 18.4 Mbps of combined throughput
- Provides data service up to 15 Mbps
- Consolidates corporate data, Internet, on net and off net voice via multi-link access
- Aggregates traffic of existing CPE equipment
- Increases reliability of access links via patent-pending ATM bonding technology
- Offers four T1 and one Fractional T3 data ports for data access
- Four T1 channelized voice ports
- Flexible quality of service accommodates real time services
- Replaces need for T1 CSU/DSU

Major Applications

- Fractional T3 service over copper
- High-Speed Internet/Intranet access
- LAN-to-WAN Connectivity
- ATM-based LAN-to-LAN Connectivity at Ethernet Speed
- Campus/Multi-tenant Applications
- Video Conferencing
- Distance Learning
- Voice over IP

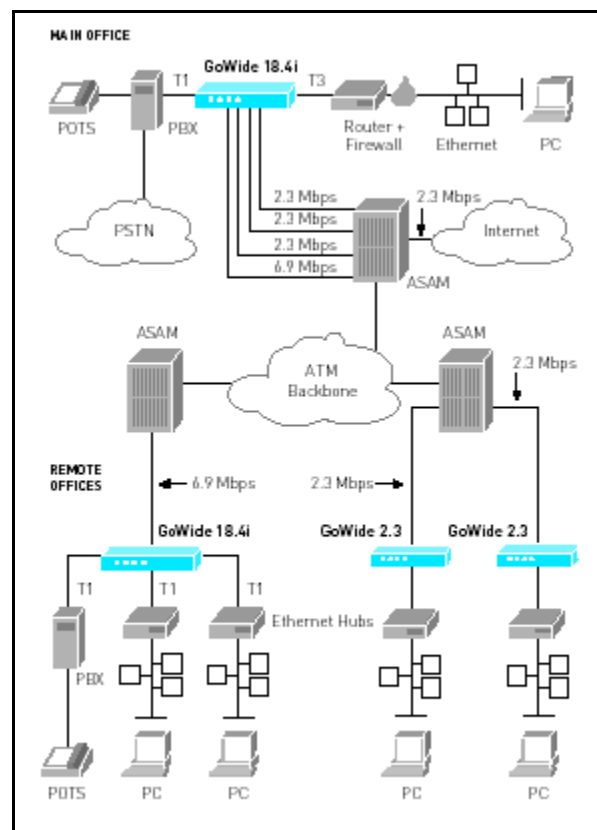


Figure 8: GoWide 18.4i Intranet and Internet Application

Repeating

Technology

Repeated SHDSL is an operation covered under the SHDSL standard (ITU-T G.991.2). The SHDSL standard allows for up to 8 repeaters to be connected serially to extend the reach of SHDSL service. In theory, this would allow a 1.5Mbps SHDSL signal to be extended out to 90000 feet.

The ability to repeat an SHDSL signal ensures the potential for a ubiquitous deployment of SHDSL service. This offers any provider the benefits of greatly increasing their serving area and offering a universally available, reliable symmetric high-speed business class service.

As illustrated in Figure 9, the process of repeating an SHDSL signal is accomplished by regenerating the incoming SHDSL signal at equal intervals along the SHDSL span. The signal is actually being re-generated and not just amplified, thus ensuring that all noise is filtered out. This process ensures that signal integrity and throughput levels are all maintained.

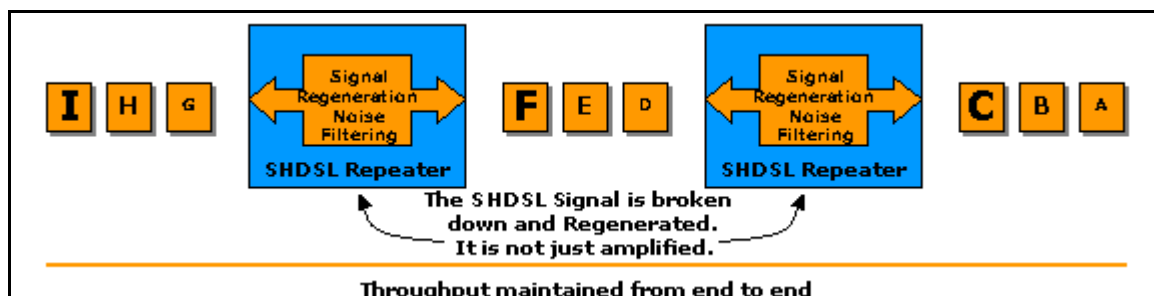


Figure 9 SHDSL Repeater

The standard for repeated SHDSL not only includes single pair (2-wire SHDSL), but also includes 4-wire SHDSL. In addition, because SHDSL IMA is an implementation using a group of 2-wire SHDSL circuits, it too can be repeated providing the ability to offer 9.2Mbps service at very large distances from the central office.

Deployment Requirements

Figure 10 illustrates the generic requirements for a repeated SHDSL deployment. The main components of the deployment are an SHDSL CPE, a DSLAM capable of supporting the SHDSL standards, a series of SHDSL repeaters and the copper pairs connecting the network.

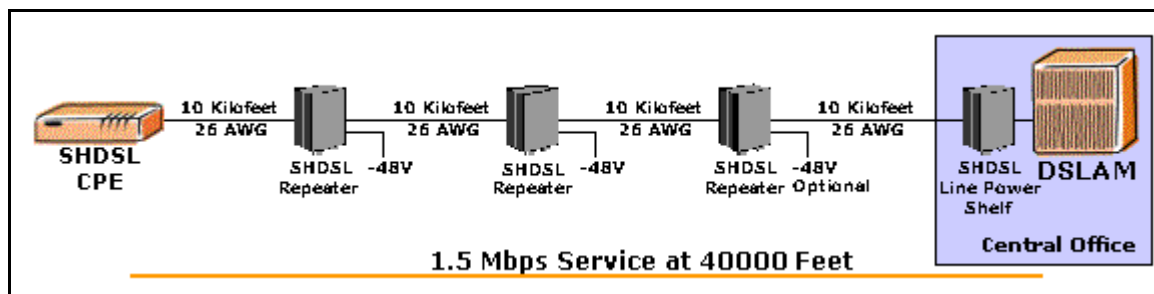


Figure 10 Generic Repeater Deployment Requirements

Each repeater can typically be wall or pole mounted in a standard 400-type mechanic. The first repeater in the chain can be span powered from a line power shelf located in the central office along with the DSLAM. Span powering is very convenient and minimizes deployment costs and complexity, especially in cases where only one repeater is required. Further repeaters will require a –48 Volt power source.

Repeaters can be put in at any interval, but will only maintain the rate attainable at those distances. As an example, if a rate of 2Mbps is attainable at 7000 feet without a repeater and the 2Mbps service is needed at 20000 feet then two repeaters would need to be installed at no more than 7000 feet apart. Similarly, if a rate of 1.5Mbps were attainable at 10000 feet, only one repeater would be required at the 10000 foot mark to ensure 1.5Mbps service at 20000 feet.

Product Descriptions

Symmetricom's GoLong SHDSL Loop Extender System

Symmetricom's GoLong G.shdsl Loop Extender System extends the effective range of G.shdsl circuits. This allows Network Service Providers to offer high-speed (2.3 Mbps to 9.2Mbps) G.shdsl service at more than double the service coverage area.

The GoLong G.shdsl Loop Extender System consists of a Line Power Shelf, Two-Port Line Power Cards (SLE-C), G.shdsl Repeaters (SLE-R), and an Alarm Card (SLE-A). The Line Power Shelf has 16 slots for Line Power Cards and 1 slot for an Alarm Card. The Line Power Card is NEBS and Bell Core 1089 compliant. The Line Power Card has two ports with each port able to power the G.shdsl Repeater at distances up to 3 Km (10 kilofeet) on a 26 AWG. This eliminates the need for local power, reduces deployment cost, and shortens installation time. The Repeater performs the operation of a midspan Doubler in the G.shdsl circuit.

The Repeater can be installed in any housing that accepts a 400-type mechanic. The Alarm Card receives and processes alarm signals from individual Line Power Card located within the shelf. The Alarm Card also provides alarm signals to the Central Office Alarm Systems. Symmetricom's GoLong G.shdsl Loop Extender System extends the effective range of G.shdsl circuits. This allows Service Providers to provide high-speed 2.3 Mbps G.shdsl service to longer reach customers, and increase the service coverage area.

Symmetricom's GoLong G.shdsl Loop Extender System built-in status LEDs, and standard G.shdsl Embedded Operations Command support facilitates diagnostics and management. Symmetricom's GoLong G.shdsl Repeater automatically adjusts to the payload rate provided by the DSLAM. This reduces installation time, and streamlines the provisioning and field installation process.

Symmetricom's GoLong G.shdsl Repeater comes with flexible mounting accessories facilitating wall installation or pole mount, indoors or outdoors. Symmetricom's GoLong G.shdsl Loop Extender System design, manufacture, and support are performed entirely by Symmetricom, a recognized leader in Network Synchronization and Timing. Symmetricom's manufacturing facilities are fully ISO 9001 certified, and meet Telcordia GR-2981 CORE requirements. In addition, the GoLong G.shdsl Loop Extender is backed by Symmetricom's world-class Customer Technical Assistance Center (CTAC) in the United States and the United Kingdom. The CTAC is capable of delivering technical support coverage 24 hours per day, 7 days per week, 365 days each year to over 90 countries throughout North America, South America, Europe, Asia, and Africa.

Some key features of Symmetricom's Loop Extender System includes:

- Fully compliant with the international G.shdsl (ITU-T G.991.2) standard
- Interoperable with any ATM-based G.shdsl compliant DSLAM and CPE device
- More than double the reach of a single G.shdsl copper pair
- Span or local powered
- Auto rate adjustment
- Status LEDs
- Mounting flexibility allows for either wall or pole mounting, indoors or outdoors
- Tamper-resistant and water-resistant
- Lightning protection
- Rugged, durable design for use at -40° to +149 °F (-40° to +65 °C)
- UL, CE, NEBS-3, and environmentally hardened
- Bellcore GR-49-CORE compliant

Further Information

For more information on SHDSL or on any other products described in this document, please visit www.symmetricom.com