行政院所屬各機關因公出國人員出國報告書

（出國類別：實習）

參加2000年秋季 ISP CON 及 Comdex 網際網路研習課程報告書

行政院研考會/省(市)研考會 編 號 欄
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出國人服務機關：交通部電信總局
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出國地點：美國
出國期間：八十九年十一月七日至十一月十九日
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目　　　　錄

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壹、前言

台灣擁有自由繁榮的國際經貿環境，又位居亞太重要樞紐,先天上具有發展成為亞太營運中心的優越條件，然建立台灣成為亞太營運中心，電信中心是其中不可或缺而且也是最重要的一環，而健全的網路環境建設則是亞太電信中心最基礎的架構。有鑑於此，政府大力推動電信自由化，除了希望提供價格合理且高品質之多元化電信服務以加強國際競爭力外，更積極推動國家資訊網路建設，企圖引領台灣成為企業建立區域或全球資訊網路和管理的中樞。

近年來,隨著網際網路的蓬勃發展,上網人數倍數激增，網際網路應用及服務的不斷推陳出新及網際網路技術的日新月異，都直接衝擊現有的網路架構與設備, 因此各個網際網路服務公司無不卯足了勁，期能突破技術瓶頸，提供更嶄新的服務內容。 而為培養及充實人員對網際網路的專業知識與技能，了解未來網際網路的新趨勢以及因應不斷衍生的相關

問題，提昇第二類電信事業的監理能力，實有派員至先進國家學習網際網路相關課程之需。適逢今年秋季 ISPCON 及 Comdex 於十一月七日至九日及十三日至十七日分別在美國加州聖荷西(San Jose)及拉斯維加斯(Las Vegas)舉辦網際網路研習課程，乃奉派於八十九年十一月七日至十九日止參加該項課程，其含行程共十三日。

貳、研習課程摘述

此次所研習課程涵蓋甚廣，包含 TCP/IP 通訊協定，Voice, Fax and Video over IP 架構、寬頻網路及相關的通訊協定和標準等等，無法一一詳述，茲就未來網路的新趨勢及寬頻技術的發展敘述如下：

（一）未來網路的新趨勢：

自伯恩斯提恩(Tim Berners) 發明全球資訊網 （WWW）成為網際網路平台，而馬克安德森(Marc Andreessen)開發出 Mosaic 網頁瀏覽器以來，有人比喻 Internet 是繼印刷術、廣播、電視等發明以來，另一波改變人類文明的力量，它顛覆傳統，締造資訊革命，改變了一般人的生活方式，也

創造了企業的另一種生存模式，成就另一個知識經濟的時代。在這個資訊的社會裡，上網擷取各種資訊已儼然溶入企業、家庭及個人生活的一部份，根據美國 IDC 公司的調查，至西元 2003 年，全球上網總人數將達到 5 億，而網路資訊量也將大幅成長，可以預見下一代網路將朝下列幾個方向發展：

1. 從窄頻至寬頻網路：

透過一般傳統電話網路通訊時所需頻寬較小，未來寬頻服務則需較大頻寬。

為因應多元化的網路加值服務、未來的電子商務及整合各種公眾電子媒體，網路資訊大增已經威脅到傳統網路原有的電路交換及路由設備所能容許的範圍，對於頻寬的需求也日益殷切。根據美國的研究，對數據傳輸全球的頻寬需求將從 1997 年 273Gbps 至 2002 年變成 27,645Gbps 呈現跳躍式成長，因此未來的網路必須要具有承載更多資料量的能力，能夠提供高頻寬及高速率者，為了解決此一問題，寬頻網路服務及相關的技術、設備產品正如火如荼的開展。

2. 從電路交換到分封交換：

傳統電路交換網路 Channel 屬獨占性，而目前分封交換網路則是 Channel 共享，利用封包傳送，可以彈性運用

傳輸效率較高。

3. 從 Data over Voice 到 Voice over Data：

數據在傳統的類比電話線路傳輸的通訊型態將被數據網路上傳送語音的通訊型態所取代;就目前網路上的資訊量而言，依美國 Uunet 報告指出非語音的資訊量每年成長 800%，反之，全球的語音資訊量僅增加 4%。不僅如此，Electronicast 也預測到 2007 年非語音的資訊量所需要的頻寬將為語音資訊量所需的 20 倍，Ameritech 公司更指出到 2010 年 99%營收將來自數據傳輸所得的收益。

4. 從電的領域進階至光的領域：

光纖網路以可以承載超高容量的網路訊務成為新世代寬頻網路的主要骨幹。

5. 從只能提供語音到多種型態的通信服務：

透過寬頻技術、光纖網路的應用，未來網路提供的將是整合性的服務，可即時傳送語音、數據及影像等多媒體資訊。

6. 從有線傳輸到無線傳輸：

從傳統撥接網路上網到利用寬頻無線傳輸。

7. <u>智慧型網路應用服務豐富化</u>：

未來透過寬頻無線傳輸架構，個人身上的手錶、眼鏡、皮帶或戒指都可以與目前使用的電腦、大哥大或呼叫器等通訊產品整合，成為穿戴式，個人化貼身通訊產品。

(二) 寬頻技術的發展：

在看好寬頻網際網路的龐大市場，相關的寬頻接取技術也越趨成熟，它是利用寬頻技術提高網路傳輸速度，一般數據機最高速率為 56Kbps，ISDN 傳輸速率則在 64K 至 1.5Mbps （一般為 128K），超過 1.5Mbps 以上則為寬頻，主要包括 XDSL 或 數位用戶線路 (Digital Subscriber Line，簡稱 DSL)及 Cable Modem 等技術。發展寬頻網路技術包含核心網路(Core Network）技術和用戶接取網路（Access Network）技術。

在核心網路技術方面是以 SDH（Synchronous Digital Hierarchy）、DWDM（Dense Wavelength Division Multiplex）、ATM 及 MPLS（Multi-Protocol Label Switch）為主而在用戶接取網路技術方面目前

有下列幾種方式：

- 有線電視網路混合光纖同軸電纜網路(Hybrid Fiber Cable, 簡稱 HFC)： 以 HFC 為傳輸媒介之 Cable Modem 具有頻寬較寬、傳送速率較高的優勢。頻寬可達 750MHz 甚至 1GHZ，傳送速率資料下載最高可達 10Mbps，資料上傳最高可達 1.5M，屬頻寬共享，只是頻寬共享後是否能維持高速率，則是其 QoS 的一大考驗，惟以 HFC 為傳輸媒介，對於電視之整合性較高。
- 非對稱高速用戶迴路 (Asymmetric Digital Subscriber Line，簡稱 ADSL)：所謂非對稱式是指由伺服器到使用端（下行）的傳輸數率大於由使用端到伺服器（上行），其中提供上傳為 64Kbps 到 640Kbps，而下載為 1.5Mbps 至 9Mbps 的速度。由於 ADSL 架構中，採分封方式（Packet Mode）傳輸資料，語音與數據均在相同的線路上傳，利用原電話銅絞線的高頻帶傳送數據，低頻帶傳送語音，不僅可快速上網且同時進行語音通話，其用戶與機房間的傳輸距離越短，速度越快；反之，則越慢。因在

傳輸時的訊號損耗非常明顯，因此用戶迴路有距離五公里之限制。於用戶端除了裝上 ADSL 數據機外，還必須裝一個分離器 (Splitter)。ADSL 最大優勢是在於屬「用戶獨享」頻寬架構，在保密及安全方面有 Cable Modem 無法取代的優勢。

- 衛星直接上網 (Direct PC)：傳輸模式是單向傳輸，且透過兩個不同頻道傳送資料。在下載資料時，是透過衛星，惟在上傳資料時，仍必須透過一般數據機撥接上網。使用高速衛星網路服務(Turbo Internet Service) 時，以 400Kbps 的速度傳輸，而以衛星多媒體傳送服務(Multimedia Transmission Service) 及 衛星封包快遞(Package Delivery Service)，則可達 3Mbps。
- 無線區域多點傳輸系統(Local Multipoint Distribution System，簡稱 LMDS)技術：如採用 LMDS 以分封式通信協定來建置無線用戶迴路時，使用頻率為 28GHz，其頻寬可高達 155M bps，發射距離約在 3 到 5 公里，具有雙向互動性功能，可提供多媒體資訊，另建設時間短，成本低。其典型的建置方

式係構建一個具全方位天線的中心基地台，服務其周遭具有配備指向性碟形天線的客戶。此種接取方式因其傳輸頻段易受到天候影響，而降低傳輸品質之穩定性。

另未來寬頻技術還包含：

- 藍芽技術 – 是一種短距離無線通訊標準，利用 2.4GHz 頻帶傳輸的 IEEE802.11 標準，為了因應智慧家電（Intelligent Appliance，簡稱 IA）時代的發展，1998 年 5 月，由 Intel、Ericson、Nokia、IBM 及 Toshiba 共同制定出一套短距離射頻無線連接技術的標準。有效距離十公尺內，可延長至一百公尺，其應用是讓膝上型電腦與印表機、行動電話與受話器、Palm 掌上型電腦與自動販賣機等各式裝置互通訊息，且可提供上網。
- 端對端(Peer-to-Peer)傳輸 – 是網際網路平等化利器，使功能最低階的個人電腦，只要能上網，就能成為讓外人擷取所需之資訊庫。音樂檔案互換軟體 Napster 是第一種將端對端技術大眾市場化的應

用。

- 延伸標示語言（XML）- 是較目前超文件標示語言(HTML)更複雜的網路資訊編碼技術標準，可以加快網頁顯示速度，使全球資訊網成為更有用、更多元化的工具；因此業者與業者間之界限越加模糊，整合性服務業將是未來主流。

參、觀感與結論

1. 網際網路的熱潮正席捲全球，成為下一世紀企業競爭之角力場，其發展更攸關國家整體經濟之發展，因此全球各國無不致力於資訊與通訊科技的發展，尤其未來網路應用的電子商務市場更是百家爭鳴之地。我國近來加速開放電信市場民營化的成績是有目共睹，然而依據 EIU 及 IDC 的評比調查顯示我國在「通訊與資訊基礎方面」及「電子商務交易的活絡程度」仍略嫌不足，因此建立完善的網路環境包括連網設備、通訊與資訊基礎建設、相關法規及安全的交易機制，是目前推動網路發展刻不容緩的議

題。

2. 寬頻時代正式引爆：

在網際網路快速發展下，寬頻網路適時解決了對頻寬的需求，其中ADSL及Cable Modem以價格低廉的優勢，迅速佔有市場，有逐漸取代撥接上網的趨勢，未來隨著固網業務開放，網路競爭將越趨激烈，因此積極鼓勵業者建置寬頻網站，提供寬頻網路服務及寬頻上網，以配合行政院國家資訊基礎建設小組(National Information Infrastructure, 簡稱NII)於去年七月推動全民寬頻上網的國家型計畫－三年內以300萬人為目標，將有助於寬頻網路的普及化，使全民都能享受網際網路帶來的生活便利與實質利益。

3. 網際網路革命突破時間、空間的限制，掌握全球的脈動，形成地球村，創造了經濟的奇蹟，但同時也帶來了負面的衝擊，造成數位落差及網路歧視等問題，因此面對這些問題，於個人須有終身學習之態度，於政府組織則應有變革管理能力及心裡準備，以一個高效能政府來落實推動改革工作，使從上到下都能具有

創新的觀念，建立以民眾需求為導向的服務制度，積極公開政府資訊，進一步落實電子化政府，以確實達成善用科技的高效率經營。

肆、附件（研習課程資料）

附件一：Understanding the Telecom Revolution

附件二： Next Generation Broadband Networks

附件三： Broadband Access Alternatives

附件一

LIDO Telecommunications Essentials™
Understanding the Telecom Revolution

Lili Goleniewski
The LIDO Organization, Inc.
www.lidoorg.com
lili@lidoorg.com
415-457-1800

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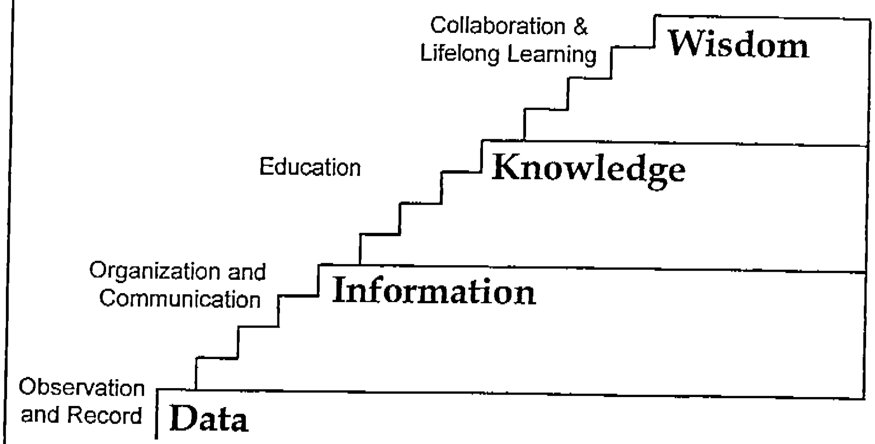
www.telecomwebcentral.com

LIDO

1

What is Information ?



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The Information Age

- Knowledge-oriented society
- Communications & computer infrastructure
- IT dominant business investment
- Acceleration of computing power
- Networked intelligence
- Bandwidth abundance
- Network evolution

3

Knowledge Age Characteristics

- Digitalization
- Virtualization
- Electronic proximity
- Multimodal information flow
- Multisensual communications
- Ubiquitous computing
- Affective computing

LIDO 4

The Age of Intelligence

- Moore's Law
  - processing power doubles every 18 months
- Distributed intelligence
  - ubiquitous computing, intelligent appliances
  - smart houses, home area networks (HANs)
  - mobile platforms, affective wearables, personal area networks (PANs)
  - tagging the human being, artificial intelligence, artificial life

LIDO 5

The Age of Intelligence

- Digital entertainment is driving computing
  - the latest processors support fast visualization of large data sets, and intensive math for real-time simulations
  - applications include graphics, 3-D games, astronomy, the biosciences and predictive modeling
  - platforms are converging - PCs, digital TVs and game consoles will share three things in common
    - broadband access, high-performance processors, and a variety of human-centered input-output devices

6

The Age of Intelligence

- Advanced network semiconductors
  - Networking has replaced the PC industry as the real driver of innovative semiconductor designs
    - Dataquest estimates that the worldwide network switch chip market will top US$900 million in 2002
    - IDC projects that the emerging network-processor subset will be worth US$300 million or more around 2002
    - Key suppliers include Agere, Broadcom, C-Port, Galileo, Intel, LSI Logic, Maker, MMC Networks, Motorola, NetLogic, Siara, SiTera, Texas Instruments, T.Sqware, and Vertex
    - Goal is to provide equipment makers with more powerful, flexible and tightly-integrated processor platforms that will also simplify and speed up product development cycles.

LIDO 7

Ubiquitous Computing

- Take computers out of boxes and put them into ordinary things
- Smart things will be able to take care of themselves
  - smart food, smart wrappers, smart cloths, smart needles
  - smart cupboards, smart refrigerators, smart medicine cabinets, smart portable scanners
  - smart cars, smart highways
  - smart materials, smart structures, smart places

LIDO 8

Ubiquitous Computing

- New breed of interactive, omnipresent and invisible computers have been made possible through recent breakthroughs in the development of sensors, detectors and electrical fields
- Media Lab's Things That Think consortium
  - Initially over 40 sponsors include Nike, Swatch and Lego

LIDO

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Ubiquitous Computing

- Scanning software for brain activity is getting better
  - the day may come when a headband can read where brain activity is taking place.
- Mind of the Market lab at Harvard Business School
  - researchers peering inside shoppers brains to develop more effective advertisements and marketing pitches
  - using imaging techniques that measure blood flow to various parts of the brain, the team predicts how consumers will react to particular products and discover the most effective ways to present information
  - could radically alter how firms develop and market new products

LIDO

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Ubiquitous Computing

- Harvard researchers believe the scans can also forecast future purchasing patterns
  - "It is possible to use these techniques to predict not only whether people will remember and have specific emotional reactions to certain materials, but also whether they will be inclined to want those materials months later."
  - Corporations funding the projects include Coca Cola, Eastman Kodak, General Mills, General Motors, Hallmark, Johnson & Johnson and Procter & Gamble
- Ultimately the computer will analyze whether the wearer is sad or happy, tense or relaxed, and adapt its programming to their state of mind.

LIDO 11

Ubiquitous Computing

- Australia has invented a biological sensor that instantly detects the presence of a hormone, virus, drug or pesticide, blurring the line between a living thing and a computer.
- The future environment is one where objects have an awareness.
- Who owns the often personal and private information dispersed across this worldwide network of chattering computers?

LIDO 12

Ubiquitous Computing

- The question of power
- Media Lab is working on the idea of a tiny dynamo in the heel of the shoe. When the user walks, they generate enough energy to keep a computer charged.
- The PAN makes use of the body's natural electrical field, harnessed to antennae woven into the fabric of a shirt. This could transmit power to a badge computer.

LIDO 13

Changing User/Traffic Profile

- Shift to machine-to-machine communications
  - today we have
    - 6 billion people
    - 14 billion microprocessors
  - by 2001 (Uunet, John Sidgemore)
    - The typical business professional will have an average of 5 IP devices on or in them
  - by 2010 (Ernst & Young)
    - 10,00 0 telemetric devices for every human being on the planet
  - by 2010 (BT Labs)
    - 95% of the traffic will be machines talking
    - 5% of the traffic will be people talking

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Applications Evolution

- Growth in non-voice traffic
  - voice growth rate 4%-6% per year
    - 1999 = 56%
    - 2001 = 42%
  - data growth rate 30%-40% per year
    - 1999 = 34%
    - 2001 = 44%
  - video growth rate 50% per year
    - 1999 = 10%
    - 2001 = 14%

Applications Evolution

- Multimodal, multisensual communications
  - audio, visual, olfactory, tactile, kinesthetic
- E-Commerce
  - content management, product configuration, transaction platforms, supply-chain management, customer profiling
- M-Commerce
  - mobile e-commerce, locating & tracking the mobile consumer, location-based online services
- Network intelligent applications
  - Serviceware – combines high-level applications for requesting network services with underlying intelligence for fulfilling those requests
    - Serv iceware products make heavy use of content selection software and caches at the network perimeter, as well as QoS throughout the network

Applications Evolution

- Digital Entertainment
  - music, theatre, cinema, radio, television, games, gambling are all converging on digital media and digital platforms
  - video editing, digital content creation, digital imaging, 3-D gaming, virtual reality apps
  - revenues from recreational and educational software for computers, video consoles, and the Internet rose to US$5.5 billion in 1998, up from US$3.2 billion in 1995 (ISDA 1999 /State of the Industry report)
    - video game rentals added US$800 million in 1998

LIDO 17

Applications Evolution

- Digital Entertainment (continued)
  - The interactive entertainment software industry responsible for creating these products did so with only some 70,000 employees - compared to the motion picture business which generated US$6.9 billion, but employed more than 240,000 people to do so.
  - Games are anticipated to be the battlefield over which the war for control of the home computing will be fought.
    - Sony PlayStation 2 versus PC platforms

LIDO 18

Applications Evolution

- 80 percent of American consumers want high-speed access to the Internet
- Fifty-three percent will pay the high premium to watch what they want when they want.
- Seventy percent of the Internet generation have a television in their own room.
  - The Internet generation (N-gen) consists of computer literate people aged 9 to 17.

Source: The Myers Group, NY

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Applications Evolution

- Internet TV
  - An Internet service for home TV use.
  - Uses a set-top box that connects the TV to a modem and telephone line. The user interface has been specialized for viewing on an interlaced TV screen rather than a computer monitor.
  - WebTV, introduced in 1996, was the first such service to obtain widespread distribution.

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Applications Evolution

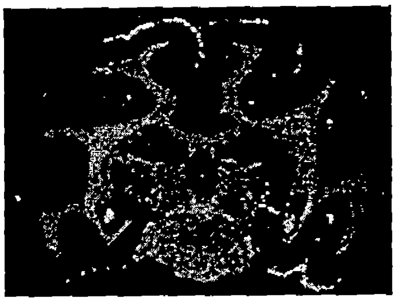
- Interactive TV
  - Two-way communications between the TV viewer and service providers.
  - Interactive television lets users find a show with interactive channel guides and save it on a hard drive for digital playback at their convenience and create personalized channels for automatic recording. They can also hunt down information on the Web through keyword searches.
  - Interactive television will allow advertisers to target their audiences more directly. Viewers, in turn, can choose to rid their programs of commercials, but they can also choose to click on a longer version of an advertisement and buy the product

LIDO 21

The Human is a Multimedia Information Processing System

Audio

Visual



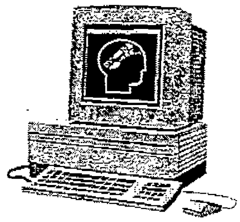
Tactile

Kinetic

Mind Operates on Sensations to Create Information For its Own Use

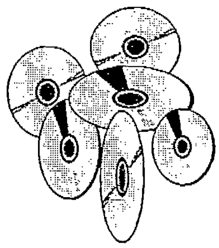
LIDO 22

Multimedia: Why ?



Understanding of Information
(percentage derived via.....)

- ◆ Written Word 7%
- ◆ Audio Cues 38%
- ◆ Visual Information 55%



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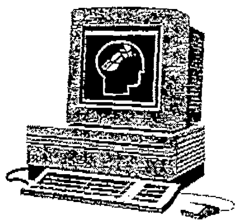
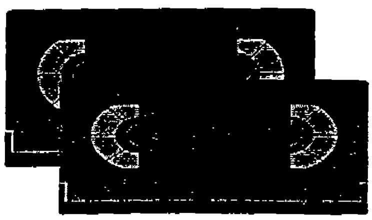
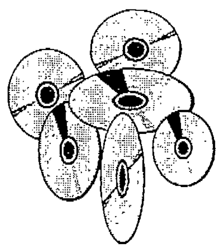
Multimedia: Why ?



Retention of Information

- ◆ 20% of What We Read
- ◆ 30% of What We Hear
- ◆ 50% of What We See





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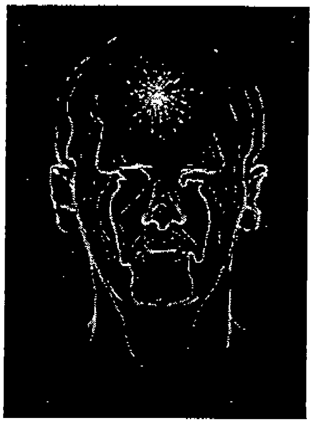
Bandwidth of Consumption of Human Senses



Hearing	640 Kbps
Smell/Taste	N/A Chemical Response
Touch	13 Mbps
Vision	
Optic Nerve Capacity	1 Gbps
Head/Eye Tracking	7 Gbps
Full Spatial Model	880 Gbps

LIDO

25

Hearing

- Teaching computers to hear and understand human speech.
- Jupiter, MIT Lab for Computer Science is a combination of four software packages
  - voice recognition, word hypothesis
  - software to determine meaning
  - then scans weather service reports on Internet
  - voice synthesizer responds

LIDO

26

Smell

- There are millions of odors in the world, each one of which can influence mood and behavior.
  - Aromas can help induce consumers to spend money
    - British Airways business class lounge at Heathrow exudes the smell of freshly cut grass and the tangy scent of the sea
    - Thomas Pink, famous shirtmakers in London's Jeymyn Street, is trying the smell of newly washed linen
    - Car dealerships in the U.K. are testing the fragrance of fresh leather in the showrooms
    - Kiotech International has demonstrated that a blend of pheromones caused shoppers to linger longer and spend more money
    - Pheromone sachets, "Excite", available through vending machines in clubs in Northern England, are outselling condoms four to one.

LIDO

27

Smell

- DigiScents (www.digiscents.com)
  - Working on a smell box called iSmell
  - The device reads a digital scent file from a Web site, creates a smell from a "palette" of 128 chemicals stored in a cartridge, and then wafts into the air with a small fan.
- AromaJet (www.aromajet.com)
  - Their device, Pinoke, dispenses smells coinciding with a player's action in a video game.
  - Has several patents on a microjetting technology that enables software code to control the selection and mixture of fragrances for release at precisely the right time coinciding with on-screen events.

28

Smell

- Growing interest in made-to-order odors
- Companies are investing in the creation of "corporate smells" to go along with their corporate logos
- We are moving towards telephone sniffers to use in medical diagnostics, electronic noses in every doctor office, and credit-card sized devices to monitor health conditions like ulcers and diabetes.

LIDO

29

Smell and Taste

- TriSenx (www.trisenx.com)
  - Has obtained a patent for technology that uses a desktop priter-like device to produce smells based on data programmed into a Web page.
  - It allows a user to download a smell or taste from the Internet
  - TriSenx devices imprint both smells and taste. Currently smells adhere to a fiber cardstock paper. In coming months, smells will adhere to a communion-like wafer that will allow people to taste a particular flavor

30

Taste

- Like smell, taste is difficult to pin down
  - 8,000-10,000 taste buds, each with 50-75 chemical taste receptor
  - taste receptors have short life cycle, 10 days, like watching aging
  - World's first tongue wire-tap at University of Michigan. It is a sieve electrode, a silicon disk only 4nm in diameter. Creates a computerized taste receptor
  - The device could serve as a neural interface to connect the body to anything, treating nervous system disorders.

LIDO

31

Touch

- inTouch, created at MIT, is a computer program that creates a direct link between two people separated by physical distance.
  - Using force-feedback technology, which allows users to physically interact with computers, the inTouch system brings people together through the manipulation of two identical objects
- The Age Simulator
  - Allows the wearer to feel, hear and see exactly what it's like to be a senior citizen

LIDO

32

Sight

- Enhancing the sense of sight, even restoring it, via the use of light-emitting diodes, lasers and advanced computer technology.
- Virtual Retinal Display - Washington's Human Interface Technology Lab (Seattle)
  - paints image directly onto retina
- Will give people hypervision, the equivalent of bionic eyes
- Commercial product due for release in 1999 from Microvision

LIDO

33

The New Public Network

- End-to-end digitalization
- End-to-end optical networking
- Intelligent, programmable networks
  - distributed logic and databases
  - high-speed common channel signaling
  - open application program interfaces (APIs)
- Broadband infrastructure
  - high capacity, multichannel transmission lines
  - high-speed fiber and broadband wireless transmission
  - low latency networks
  - multiservice, agnostic platforms
  - quality of service guarantees
  - encryption and security services

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34

The New Public Network

- From Narrowband to Broadband
  - from single channel to multichannel
  - from low bandwidth to high bandwidth
- From Circuit switched to Packet switched
  - from exclusive channel to shared channel
- From Data over Voice to Voice over Data
  - from data over circuit-switched analog voice network to voice over digital data packet network
- From Electronic to Photonic
  - shift from electronic networks to optical networking

LIDO

35

The New Public Network

- From Singlemedia to Multimedia
  - from voice to multimodal communications
- From Fixed to Mobile
  - from fixed wireline connections to mobile wireless communications
- From Portable to Wearable
  - from unresponsive standalone devices to affective wearable computers

LIDO

36

Changing Organizational Structure

- Characterized by market diversification, internationalization and workforce decentralization
- Growth of non-traditional work environments, hence workers requiring remote broadband access
  - SOHO environment
    - currently 37 million SOHOs in US, expected to grow to 50 million by the end of 2000
  - Teleworker, telecommuter, remote access worker
    - telecommuters in the US numbered 26.8 million households
    - 28% of the top companies offer telecommuting as an option
  - Virtual office
  - Knowledge intensive professional

LIDO

37

Changing Network Value

- IT dominant business investment
- IT is element of strategic development
- IT is a competitive necessity
- Positive environmental impact
- Emphasis on high quality network service
- Greater risk with failure/disruption
- Increased security concerns

LIDO

38

Cost of Downtime (per minute)

• Brokerage operation	US$107,333
• Credit card/sales auth.	US$ 43,333
• Pay-per-view	US$ 2,500
• Home shopping (TV)	US$ 1,883
• Catalog sales	US$ 1,500
• Airline reservations	US$ 1,500
• Tele-ticket sales	US$ 1,150
• Package shipping	US$ 467
• ATMs	US$ 242

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Source: FCA
Internet Telephony 9/27/99

39

Changing Network Management Role

- Critical to business success
- Information/network risk management
- Business recovery management
- Contingency/disaster recovery planning
- Change management
- Service creation & management
- Integrated network management
- Outsourcing

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40

What is Converging?

- Networks Infrastructures
  - PSTN, Internet, Wireless, Broadcast, Cable TV, Corporate Back Office
- Network Services
  - Local, Long Distance, Wireless, Internet, Hosting, Applications Partnering, Security, Firewalls, Legacy Systems Conversion, Settlement
- Devices
  - Television, Telephone, Computer, Appliances, Clothing & Jewelry, Tattoos, Neural Implants

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What is Converging?

- Applications
  - Communications, Information Services, Entertainment, E-Commerce, Affective Computing
- Industries
  - Biotechnology, Computing, Consumer Electronics, Entertainment, Publishing, Power Utilities, Telecommunications
- Man & Machine
  - Artificial Limbs and Organs, Intelligent Implants, Neural Interfaces, Artificial Life

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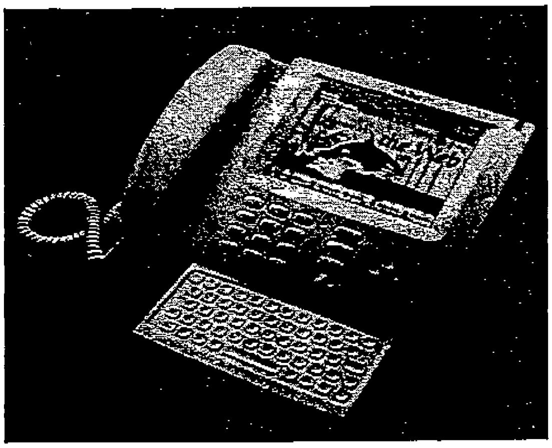
The iPhone



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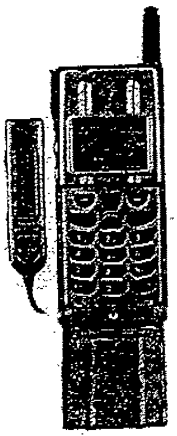
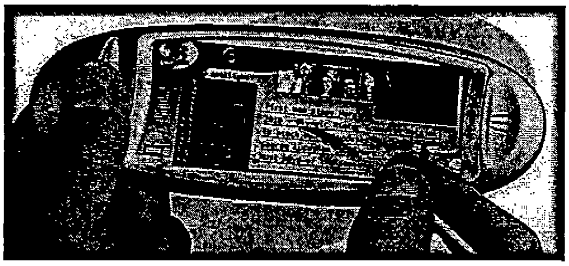
Convergence
Communications and Entertainment



44

Super Phones



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Source: Scientific American 10/00

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Wireless Network Devices

Wrist Communicator

Ski Goggles that will internally display your route

Pocket-Size Travel Guide

LIDO

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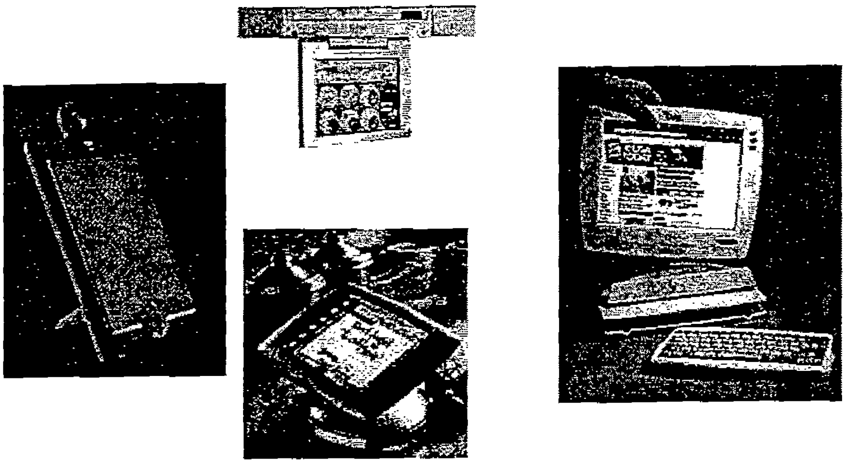
Intelligent Appliances



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Large Plasma Screens

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Interactive Features

Thompson's
TAK
System

Nokia's
Media
Screen

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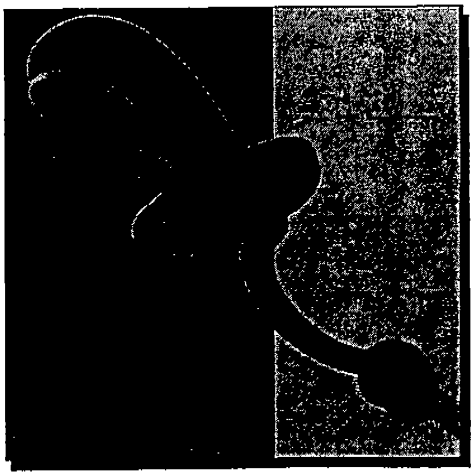
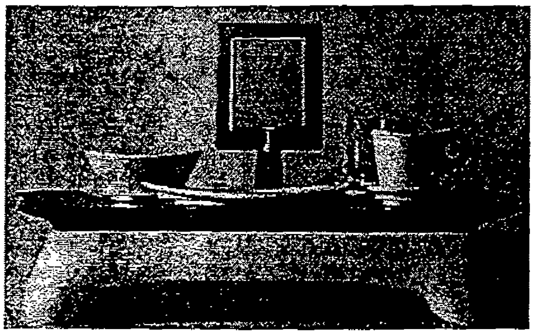
Philips Remote Eyes



LIDO 50

Wired Breakfasts



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Smart Kitchen

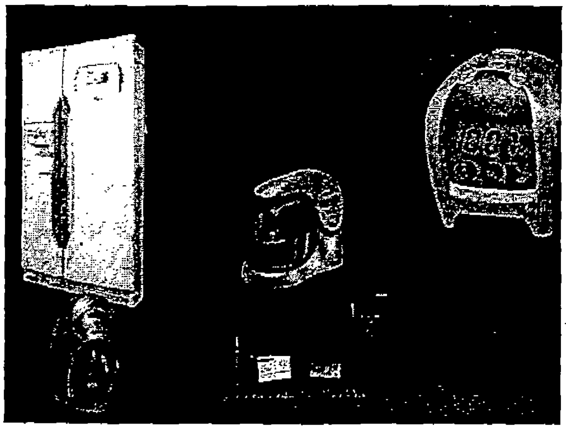
Whirlpool Networked Refrigerator

Thalia Coffeemaker

Thalia Stand Mixer

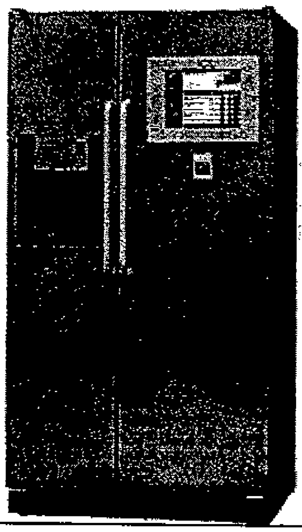
GE Microwave & Portable Web Pad

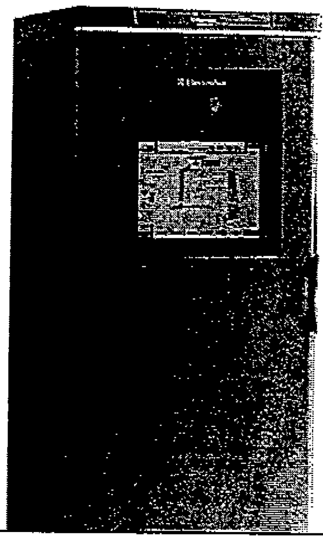
Thalia TimeHelper Clock



LIDO 52

Smart Refrigerators





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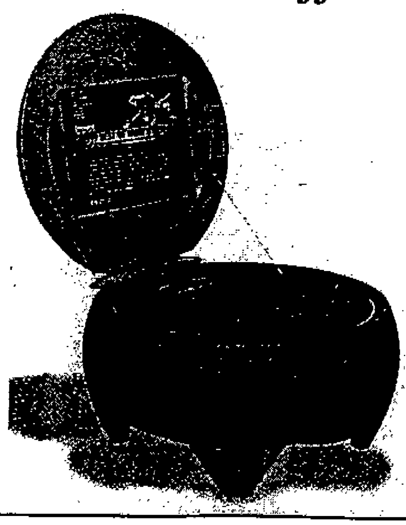
53

Multimedia Coffeetable



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High Definition Hearing Aids

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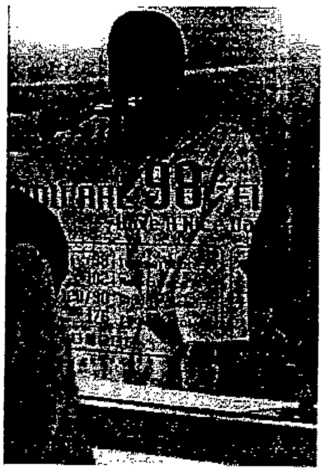
55

Doctor in the House



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Source: Popular Science 7/00e

Doc in a Box

Doctor in a Box

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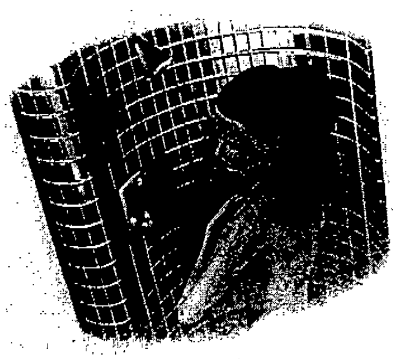
Source: Popular Science

A Hospital at Home

Smart Socks

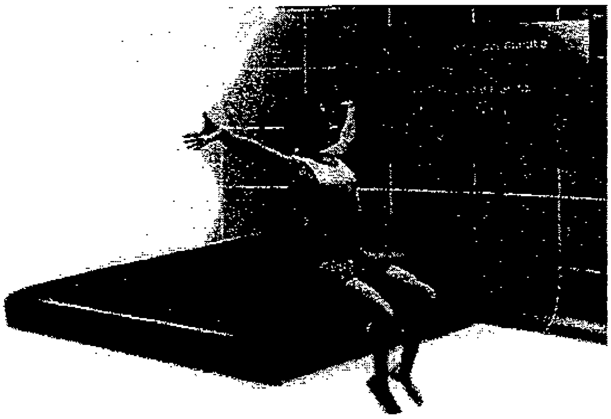
Melanoma Monitor



LIDO

Source: Popular Science 7/00

What's Next



Brainy Bed

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Source: Popular Science 7/00

What's Next

Thoughtful Spectacles

Smart Toothbrush

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Source: Popular Science 7/00

Programmable Tattoos

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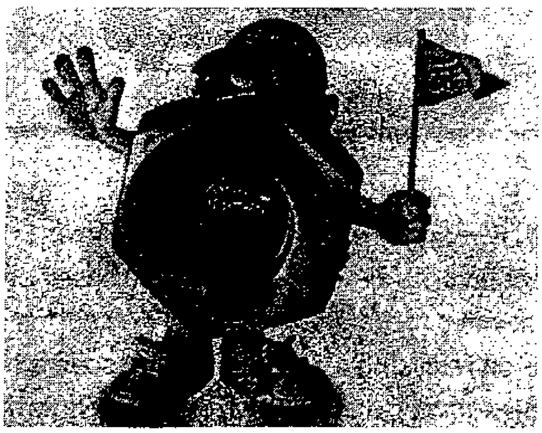
Robotic Answerman



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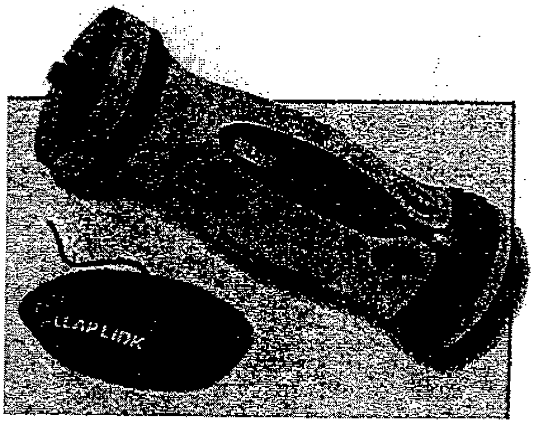
Electronic Teacher



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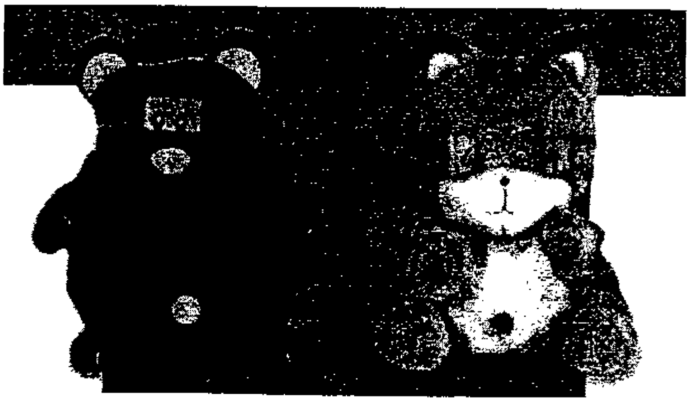
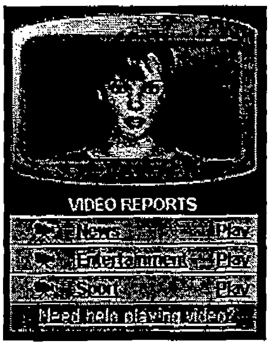
Matsushita Electric's Smart Pets Tama and Kuma



LIDO

Source: Popular Science 7/00

AnnaNova, A Virtual Newscaster



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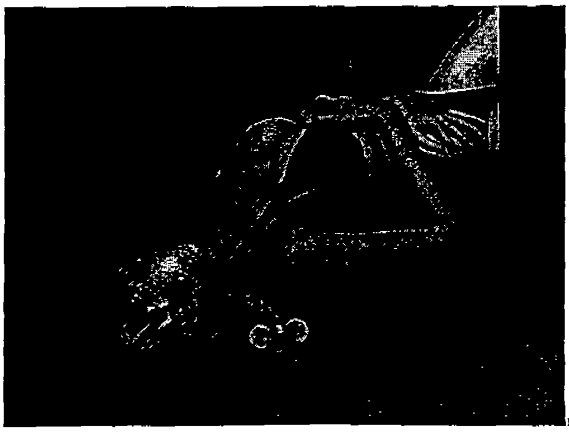
Source: Annanova.com

Virtual Models



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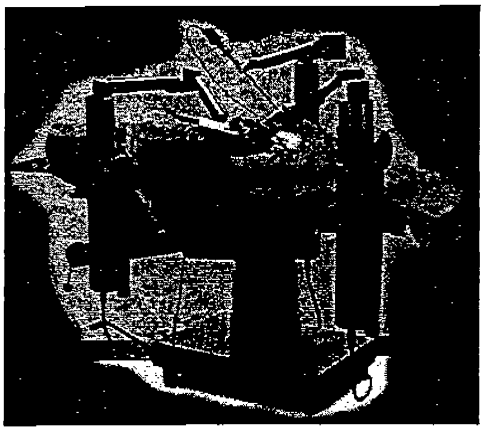
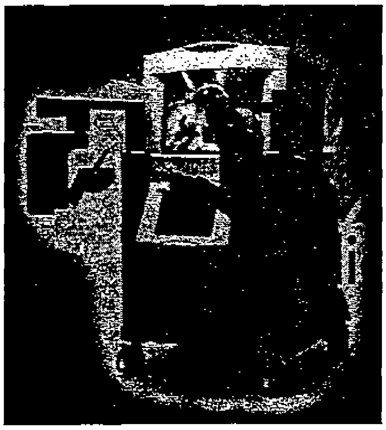
rs-und-models.de

Remote Heart Surgery





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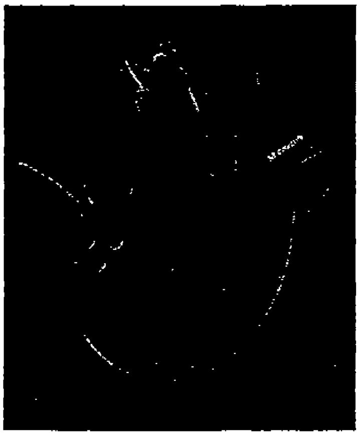
Source: Popular Science 7/00

Microsoft Joystick



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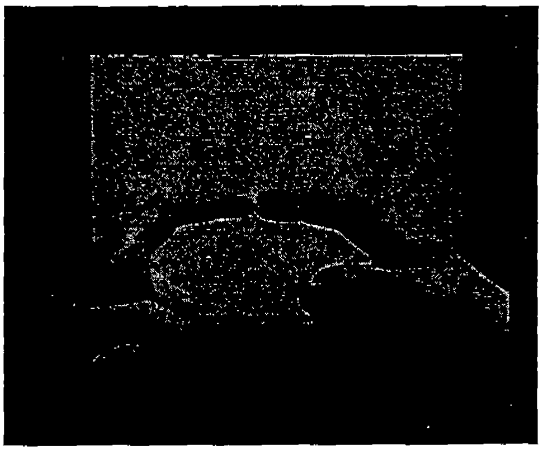
Electronic Handshake



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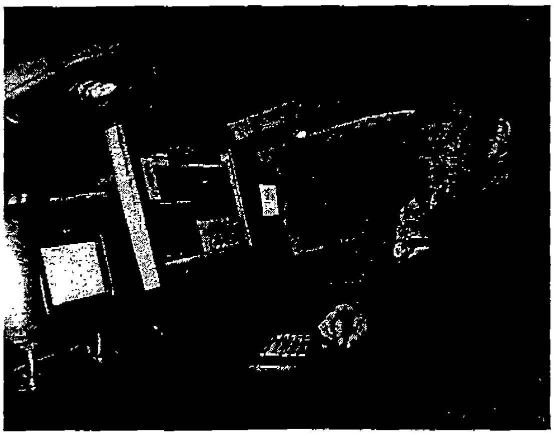
The Only Way To Surf The Autobahn



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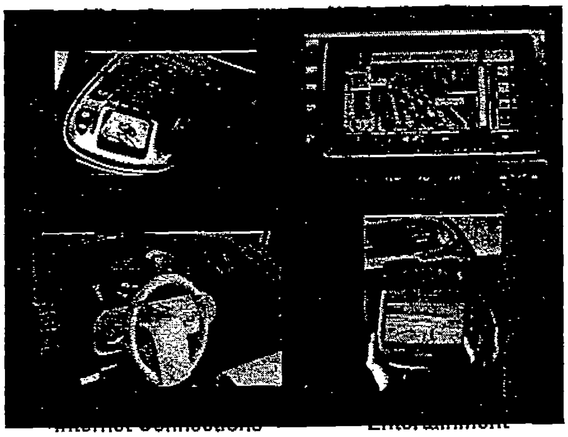
Digital Wheels



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Work & Play

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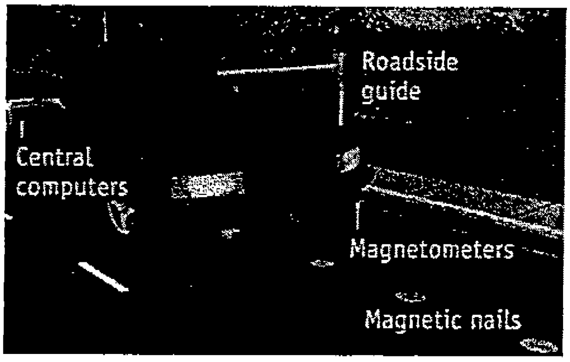
Honda's Automated Highway System Technology



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Mobile Meetings

LIDO 74

Heads Up

LIDO 75

Pool Playing Wearable

LIDO 76

Head Mounted Camera

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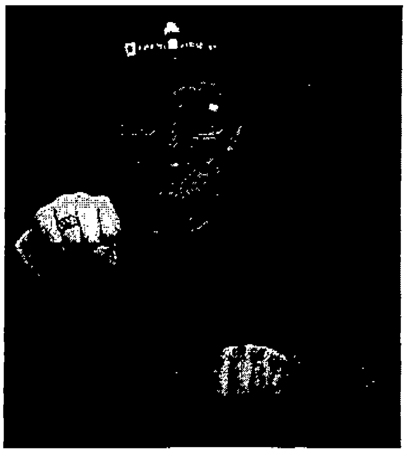
Sign Language Translator



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Wearable Evolution

Evolution of Steve Mann's "wearable computer" invention

1980	Mid 1980s	Early 1990s	Mid 1990s	Late 1990s

http://www.wearcam.org/

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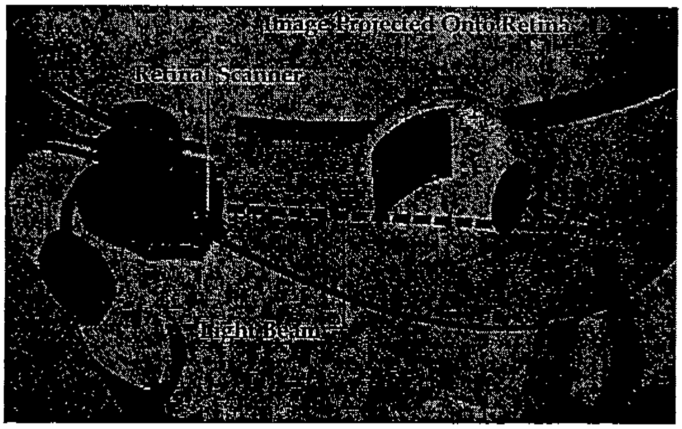
BT Talk & Scan Technology

LIDO 80

Eyeball Paintings



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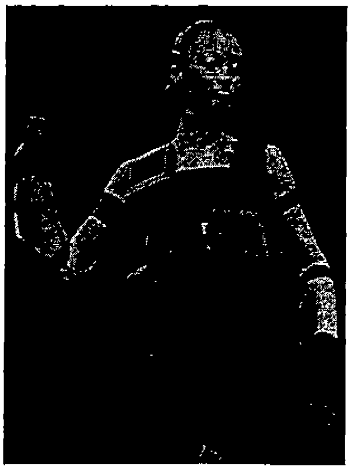
Wearable Intelligence



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Ring With Bar Code Reader

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iButton Java Ring

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Social Wearables

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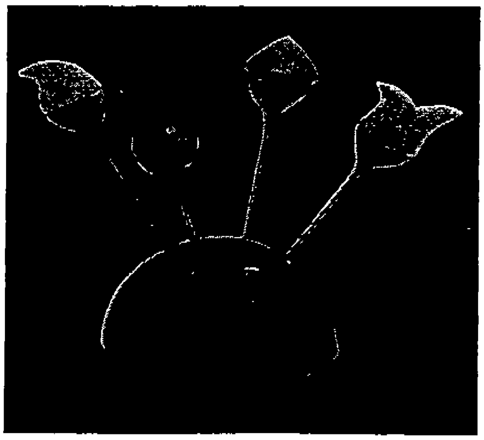
Philips Hot Badges



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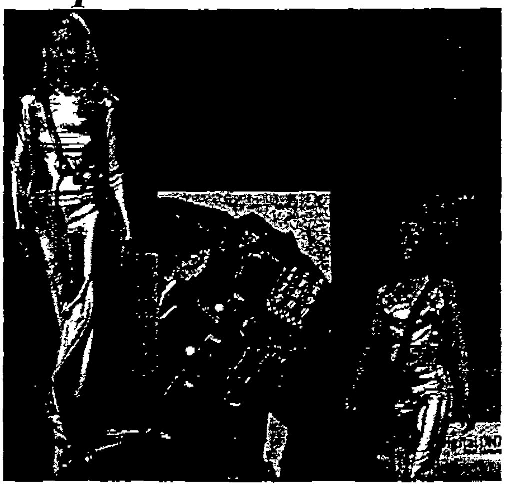
What's Next

LIDO Source: Popular Science 87

Chips Come Into Fashion

Worn Over The Shoulder, This Device Lets You Send E-mail



LIDO Source: Popular Science 88

Chips Come Into Fashion

Sensor Gloves
That Gather
Patient Data

Temperature
Regulated Co

pped
es

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Vith A
ctrometer

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Source: Popular Science

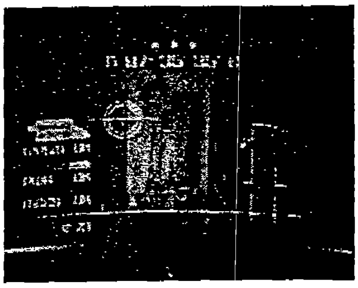
89

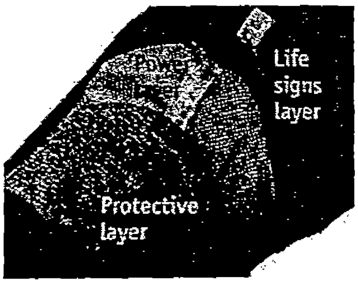
Battle Gear 2025

LIDO

Source: Popular Science 7/90

Battle Gear 2025





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Source: Popular Science 7/99

91

BT Homo Cyberneticus

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92

Many Millenniums hence…..

- Intelligent beings consider the fate of the Universe……….

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Source Age of Spiritual Machines
Ray Kurzweil, 1999

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附件二

LIDO Telecommunications Essentials™
Next Generation Broadband Networks

Lili Goleniewski
The LIDO Organization, Inc.
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lili@lidoorg.com
415-457-1800

Telecom WebCentral

www.telecomwebcentral.com

Broadband Drivers

- Increasing demand for information
- Shifting traffic patterns
- Growing network usage
- Rapid technology advances
- Unleashing of bandwidth
- Applications evolution
- Convergence forces

Communications Traffic Trends

- Data traffic is increasing by 36% each year, according to Frost & Sullivan.
- Data is growing five times faster than voice. (Bell Atlantic Corp, Data Comm 3/99)
- Data traffic predicted to require more than 20x the bandwidth of voice traffic by 2007. (Electronicast)
- Uunet reports that data on its backbone is growing at about 800% annually, compared to voice traffic worldwide increasing by only 4%.
- Ameritech reports that in 1998 data overtook voice revenues, with data at 51% and voice at 49%. They project that data will be 99% of their revenue by 2010. (Telephony 3/1/99)

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Communications Traffic Trends

- By 2001, there will be 300 million Internet users. (source: ITU)
- 7 new Internet users log on every second (Cisco)
- By 2003 the world total of Internet users will top 500 million (IDC)
- In 1997, 78.1 million devices were used to access the Web, by 2002, that number will increase to more than 515 million (IDC)
- The average connect time has grown by 45% per year, from 17 minutes per session in 1997 to 35 minutes in early 1999. (Ascend) By the end of 1999, session times were reported to be an average of 45 minutes.

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Communications Traffic Trends

- There were 63 million Internet users in the US in 1998, growing 20 to 30% per year predicted to reach a penetration of 63% by 2003. (Jupiter Comm)
- Europe currently has a penetration rate of 9%. Online households in Western Europe will triple to 31 percent by 2003. (Int'l Herald Tribune 10/9/99)
- In the Asia-Pacific region, the number of Netizens is growing at an annual rate of 99%. (Int'l Herald Tribune 10/9/99)

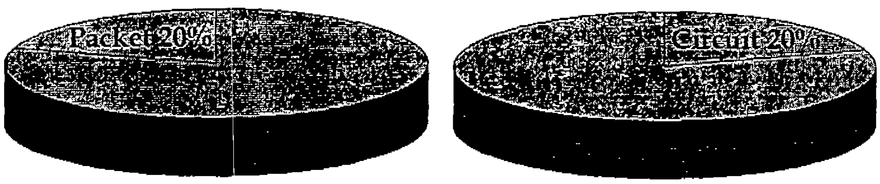
Communications Traffic Trends

- Worldwide bandwidth requirements for data will jump from 273 Gbps in 1997 to 27, 645 Gbps by 2002. (Insight Research)
- By 2002, Internet traffic will consume 90% of available bandwidth on networks worldwide, and by 2008, Internet traffic will account for 99% of the data traversing international networks. (Sidgemore, Uunet)
- Carrier revenues from IP data will only account for 25% of the total by 2003. (Insight Research)

Communications Traffic Trends

- Minutes of communication services traveling over IP telephony networks will grow from
  - 70 million and less than 0.1 percent of all PSTN minutes in 1997
  - to over 70 billion minutes and 6.1 percent of all PSTN minutes by 2003
  - reaching over 1 trillion minutes by the year 2006 (Piper Jaffray Feb 99).

Worldwide Traffic Shifts
Packet vs Circuit Switching



Traffic Today **Traffic 2005**

Source: Current Analysis, Inc, BCR 1/99
Multiservice Integration

Communications Bandwidth Trends

- The capacity of optical-fiber links is doubling every 12 months. (Lucent, IEEE Spectrum 3/99)
- Network capacity is doubling every 9 months (Red Herring 2/00)
- The raw bandwidth available by the year 2000 is expected to be 10,000 greater than in 1996. *
- Vinton Cerf estimates that by the year 2001, relative capacity of the Internet will be 2,500 times as great as today. *
- The amount of fiber deployed between 1997 and 1999 was 100 times the amount deployed in all the prior years. *
  - * Nexabit Networks white paper - Will the New Super Routers Have What It Takes

Communications Bandwidth Trends

- Fiber prices on a per Mbps basis are falling 60% each year.
- Uunet alone is anticipating a 1,000-fold growth in capacity by the year 2000.
- Qwest's network alone doubled the available bandwidth in the U.S. infrastructure over the next year.
- Together, Qwest, Level 3, Williams and IXC will have 80 times the existing throughput capacity of AT&T. Source: The Oncoming Glut of Bandwidth, BCR 8/98

Communications Bandwidth Trends

- In the U.S. alone, the new networks will increase long-distance transmission capacity by more than 2,000 times in the next few years
- The world's first petabit (1,000 terabit) network was announced by I-21 Future Communications, a subsidiary of Interoute Communications Group that is creating a fiber system across Europe.

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Communications Bandwidth Trends Wireless Communications

- By 2002, wireless capacity will increase by 20x
  - the per minute network cost will fall below 5 cents (tele.com 9/20/99)
- Data will comprise as much as 30% of wireless traffic by 2002, up from 10% in 1999. (IEEE Computer 2/00)
- Projections show that wireless will become the dominant form of Internet communication by 2008 (IEEE Computer 2/00)
  - When this happens, the "anytime, anywhere" inflection point will move the e-commerce platform of choice from the desktop PC to the the palmtop.

LIDO 12

Communications Bandwidth Trends Fiber Cable Economics

- Technology breakthroughs are having a profound impact on service providers, as seen by falling prices for intercontinental capacity
  - Measured per 64 Kbps circuit the construction cost has fallen from US$1,400 in 1988 to US$300 in 1995 to a couple of dollars per line today (Red Herring, 2/00)
  - Boston Consulting Group indicates that the average capacity cost for the equivalent of a 64 kbps voice-grade circuit will fall to about two-thousandths of a cent per minute

Communications Bandwidth Trends Fiber Cable Economics

- Operators purchasing capacity transoceanic capacity pay two charges
  - A one time charge for the bandwidth, the Indefeasible Right of Use (IRU)
  - An OA&M recurring charge for the maintenance vessels that service the cable, typically 3 percent to 5 percent of the total purchase cost
    - this has not been decreasing
      - due to how cabling systems are maintained

Communications Bandwidth Trends
Fiber Cable Economics

- Market price for a transatlantic 155 Mbps (STM-1) Indefeasible Right of Use (the standard rights that are exchanged when cable capacity is sold)
  - US$ 20 million at the start of 1997
  - US$ 10 million in 1998
  - US$ 2-3 million currently (early 2000)
  - US$ 1 million expected by 2001
- The OA&M charges have remained the same
  - US$ 250,000 in 1998
  - US $250,000 currently (early 2000)

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Communications Bandwidth Trends
Fiber Cable Economics

- As cable owners extract more bandwidth out of their cable using the latest DWDM equipment, bandwidth prices fall but OA&M charges remain relatively constant.
- Atlantic Cabling Maintenance Agreement (ACMA)
  - transatlantic cabling systems are maintained under the terms of this contract - negotiated by carriers and the cable systems maintenance contractors
  - traditional contract distributed costs based on the length and capacity of the cabling systems
  - in the new contract, starting January 2000, bandwidth will be removed from the equation, carriers will pay only by the length of the cabling systems

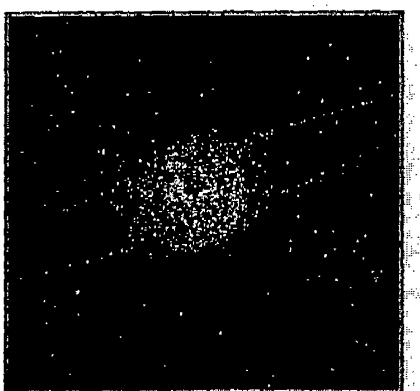
LIDO 16

Communications Bandwidth Trends Space Frontier

- There are some 220 commercial communications satellites today, this is projected to reach over 1000 by 2003 (Scientific American 4/98)
- There are 1,715 satellites in various stages of licensing at the FCC (Via Satellite 7/98)
  - 87 are in orbit, including 67 for Iridium, eight for Globalstar and 12 for Orbcomm
  - 740 Ka-band satellites planned
  - 386 V & Q-band satellites planned
  - 266 2 GHz satellites planned
  - 149 Big LEOs, 142 Little LEOs and 32 Ku-band LEOs

LIDO 17

Communications Bandwidth Trends Objects Orbiting Earth



http://cse.ssl.berkeley.edu/lessons/indiv/dataflow/HomePage.html

LIDO 18

Communications Bandwidth Trends Broadband Satellites

- Satellites are expected to account for 10- 15 percent of the broadband Internet and data access market after the turn of the century
  - Market is expected to grow from US$200 million in 1999 to US$37 billion by 2008 (Pioneer Consulting LLC)
- Merrill Lynch says the market for broadband satellites will double every year for the first five years, estimating a 94% compounded annual growth rate.
  - US$ 5 billion market 2002-2003, reaching US$ 50 billion by 2007

LIDO 19

Communications Bandwidth Trends Protecting Space

- With U.S. companies likely to invest US$500 billion in space by 2010, some military analysts believe the military will be called upon to defend American interest in space much as navies were formed to protect sea commerce in the 1700s.
  - (U.S. News & World Report Nov 8, 1999 - The New Space Race)

LIDO 20

Communications Bandwidth Trends Bandwidth as a Commodity

- The driving forces behind creating a commodities market for bandwidth are an expected bandwidth capacity surplus and a growing need for risk management.
- Philips Tarifica projects that bandwidth trading will become an US$ 8 billion annual business by 2002. They predict that by 2002 IP minutes will account for at least 23% of total global traffic, half of which will be traded over exchanges. They also forecast that Europe may take center stage in bandwidth trading. (Telephony 1/00)

LIDO 21

Communications Bandwidth Trends The Bandwidth Exchange

- Band-X
  - provides a portal for buyers and sellers of bandwidth and related wholesale services
  - Band-X has an international membership of over 7,000 people
- RateXchange
  - lead generation market and switch-based exchange
  - have transacted over 500 million minutes and currently has over 400 million minutes offered for trade
- Arbinet
  - business model based on least-cost routing and quality
  - have traded over 170 million minutes
  - approximately 50 carriers trade through Arbinet and more than 400 are registering or being connected

LIDO 22

Nielsen's Law of Internet Bandwidth

- Nielsen's Law of Internet bandwidth states that
  - a high-end user's connection speed grows by 50% per year
  - you don't get to use this added bandwidth to make your Web pages larger until 2003
- Bandwidth grows slower than computer power
- Average bandwidth increases slowly for three reasons
  - Telecoms companies are conservative
  - Users are reluctant to spend much money on bandwidth
  - The user base is getting broader

Source: Dr. Jakob Nielsen, Nielsen Norman Group
The Alertbox: Current Issues in Web Usability (April 5, 1998)

LIDO 23

Communication Application Trends

- Growth of new generations of business class services
  - E-commerce
  - Virtual Private Networks
  - Voice over IP, Fax over IP
  - Unified messaging
  - Multimedia collaboration
  - Streaming media
  - Applications hosting
  - Network caching
  - Managed wavelength services
- Business class communications require guaranteed performance

LIDO 24

Communication Application Trends

- Evolution to new models of information processing & communications
  - Ubiquitous computing
  - Human information processing model
  - Multimodal & multisensual information flows
  - Visualization
  - Telepresence
  - Augmentation, neural interfaces
  - Virtuality
- Requires tremendous bandwidth, low latency, guaranteed performance and wireless access

Communication Application Trends

- Transition from portables to wearables
  - watches with medical monitors & pagers
  - eyeglasses with embedded computer displays
  - belts & watches with embedded computers
  - rings with Universal Product Code (UPC) reader & display
  - badge based cellphones & pagers with Internet connections and tiny teleconferencing cameras
- Requires broadband wireless infrastructure

Video Applications & Bandwidth

- Growth of video and streaming media
  - digitized NTSC requires 166 Mbps
  - digitized PAL requires 199 Mbps
  - HDTV requires 1.5 Gbps
  - MPEG 1 compression offers VHS quality at 1.5 Mbps
  - MPEG 2 is compression scheme of choice, bandwidth ranges from 2.7 to 20 Mbps.
    - NTSC can be reduced to 2.7Mbps
    - broadcast quality requires 7.2 Mbps
    - DVD quality requires 10.8 Mbps
    - HDTV requires 19.4 Mbps

LIDO 27

Video Applications & Bandwidth

- H.323 videoconferencing applications
  - require 384 Kbps to 1.544 Mbps.
- Streaming video requires
  - 3 Mbps for low quality
  - 5 Mbps for moderate
  - 7 Mbps for high quality

LIDO 28

Video Applications & Delay

- Bit errors can be fatal
  - missing video elements, synchronization problems, or complete loss of picture
- Delay can wreak havoc with video traffic
  - delay, or latency, adds up with more switches and routers in the network
    - ITU recommends a maximum delay of 150 msec
    - evolving agreements promise packet loss of 1 percent or less per month and a round-trip latency guarantee of 80 msec

LIDO 29

Video Applications & Jitter

- Jitter is introduced when delay does not remain the same throughout a network.
- While video can tolerate a small amount of delay, jitter causes distortion and unstable images.
- Reducing jitter means reducing or avoiding the congestion that occurs in switches an routers as buffer delays can create jitter.
  - There should be as many priority queues as the network has QoS levels.

LIDO 30

Emerging Networks

- Traffic is growing at a significantly accelerated pace - up to 500% traffic increase in one year (London Internet exchange example)
  - More human users, more machine users, broadband access
- Established carriers and new start-ups are deploying large amounts of fiber optic cable.
- Optical technology is revolutionizing networking
- New era of abundant capacity stimulates development and growth of bandwidth hungry applications - and demands service qualities that allow control of parameters such as delay, jitter, loss ratio, and throughput.

LIDO 31

Emerging Networks

- Data traffic is equal to or surpassing voice as the most mission-critical aspect of the network.
- Integration of voice, data and video without protocol conflicts will simplify the migration of legacy communications systems and network applications to next generation transport technologies.
- The huge growth in e-business, extranets, and intranets, will require a convergent infrastructure with minimum latency to assure responsiveness.

LIDO 32

Emerging Networks

- Bandwidth-intensive applications are much more cost-effective when the network provides just-in-time bandwidth management options.
- Converged networks will provide competitive rates because of lower construction outlays and operating costs.

Converging Public Infrastructures

- Public Switched Telephone Network
  - high speed multimedia network
  - quality of service guarantees
  - ATM (Asynchronous Transfer Mode)
- Internet
  - high speed multimedia network
  - quality of service guarantees
  - ISA (Integrated Services Architecture), IntServ (Integrated Services), DiffServ (Differentiated Services), MPLS (multiprotocol label switching)

Broadband Service Requirements

- High speed, high bandwidth - measured in terabits
- Bandwidth on demand
- Bandwidth reservation
- Isochronous support - timebounded information
- Agnostic platforms - multiprotocol, multipurpose
- Unicasting - streams from a single origination point directly to a destination point
- Multicasting - reduces traffic redundancy by limiting the access to a selected group of users
- Variable quality of service parameters
- Guaranteed service levels

LIDO 35

Key Infrastructure Developments

- Photonics & optical networking
  - EDFA, WDM/DWDM, optical add/drop multiplexers, optical cross-connects, optical switches and routers
- Broadband wireless
  - Ka-band satellites, LEOs, 3G Wireless
- Multiservice core, edge, and access platforms
  - integrated access devices (IADs), convergence switches, media gateways, agnostic switches, terabit/sec switch routers
- Intelligent networks
  - distributed intelligence, programmable networking, softswitches, media gateways, SS7 gateways, service-enabling software

LIDO 36

Key Infrastructure Developments

- Broadband access technologies
  - xDSLs (x digital subscriber line)
  - HFC (hybrid fiber coax) & cable modems
  - FTTC/SDV (fiber to the curb/switched digital video)
  - FTTH/PON (fiber to the home/passive optical network)
  - DBS (direct broadcast satellite)
  - MMDS (multichannel multipoint distribution system)
  - LMDS (local multichannel distribution system)
    - also referred to as MVDS (Multipoint Video Distribution Service)
  - powerline

Next Generation Networks

- Designed for multimedia communications
  - broadband
  - low latencies
  - quality of service guarantees
- Worldwide infrastructure
  - fast packet switching
  - optical networking
  - multiservice core, intelligent edge
  - next generation telephony
  - intelligent networking
  - video & multimedia elements
  - broadband access
  - broadband wireless

Next Generation Networks

- Next generation networks stand to change how carriers provision applications and services - and how customers access them.
- End user service delivery from a single platform
  - decreased time to market
  - simplified moves, adds and changes
  - unique connection point for service provisioning and billing
- Full service internetworking between legacy circuit-switched network and next generation packet networks

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Next Generation Networks

- Must be interoperable with new structures
  - support for the most up-to-date transport and switching standards
  - advanced traffic management
    - full configuration, provisioning, network monitoring, fault management capabilities
    - capability to prioritize traffic and to provide dynamic bandwidth allocation for voice, data and video services
    - management of delay-tolerant traffic, prioritization of delay-sensitive traffic

LIDO 40

Next Generation Networks

- Embodies two fundamental concepts
  - A high-speed packet- or cell-based network capable of transporting and routing a multitude of services, including voice, data and video
  - A common platform for applications and services that is accessible across the entire network and outside the network by the customer
- Main physical components include routers, switches, gateways, servers and edge devices on the customer premises.

IP Characteristics

- IP (Internet Protocol)
  - born out of the LAN world, connectionless
    - capability of having information move between network elements without a preconceived path between source and destination
  - in LAN environment, bandwidth is relatively inexpensive and deployment is over small area
  - transit delay typically not an issue due to small area
  - in event of congestion, packets are discarded
  - TCP retransmits the lost packets, quickly and transparently to users
  - due to short transit delay, discarded packets are quickly detected

IP Characteristics

- WANs typically deployed over longer distances
- Transit delays become an issue in
  - controlling QoS
  - identifying the loss of packets due to congestion
- Bandwidth is more expensive
  - every bit sent over the WAN has a defined cost
  - packet discard can make the expense of retransmission significant
- Traditional routers were not intended to handle such large-scale networking demands as are emerging

LIDO 43

IP Router Networks

- Core is responsible for providing interconnectivity, server access, and network management to the edge devices on the network periphery
- The core network is becoming loaded, resulting in network slowness and unacceptable delays
- At the edge of the LAN, a shortage of network capacity, coupled with proliferation of broadcasts and multi-casts is creating significant network problems

LIDO 44

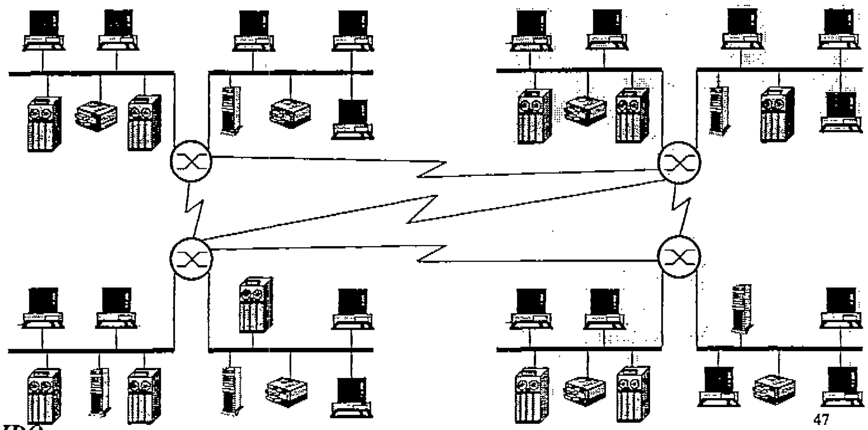
IP Router Networks

- When the edge demand exceeds the capacity of the core , buffer overruns create capacity overload and lost packets, reducing the availability and reliability of the network
- As a result, users are suffering from congestion, inadequate server access,and slow response times

IP Router Networks

- IP routers cannot deliver the service quality increasingly being demanded
- Shortcomings include poor path calculation and slow rerouting.
  - Routers use shortest path metric to calculate routes - IP routers will send traffic over a shorter congested path rather than a more desirable longer uncongested path
    - has led to increased use of ATM or MPLS (multiprotocol label switching) in the core for backbone traffic engineering purposes
  - In the event of a backbone circuit or router failure, IP routers can take up to one minute to recalculate new paths around the failure
    - has led to more reliance on SDH/SONET

IP Router Network



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Evolving in IP Networks

- Recent introductions of voice over IP services has added consideration of two other limitations of IP networks:
  - latency
  - jitter
- For a packet-based IP network to successfully support voice services, minimum transit delay must be achieved, along with minimum packet loss
  - high quality voice demands less than 100 ms. for the total one-way latency, including all processing at both ends (digitization, compression, decompression, queuing, playback, etc) as well as network delay.
    - voice compression and decompression normally takes about 30-50 ms
    - speed of light in glass is about 10 ms per 1000 miles

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Evolution in IP Networking

- One immediate solution to increase the amount of available bandwidth.
  - Technologies like DWDM will certainly provide relief, initially, but history has taught us that there is no such thing as too much bandwidth
- Key to success for large-scale IP networking lies in delivering the flexibility of IP routing with a switched packet forwarding mechanism that offers the highest possible performance and maximum network control

IP Switching

- IP switching was designed to speed up increasingly choked networks, replacing slower, more processing-intensive routers with switches
- IP routers that provide connection-oriented services at the IP layer are referred to as IP switches
- Routers are slower than switches due to the fact that they must examine multiple packet fields, make substitutions in packet headers, and compute routes on a packet-by-packet basis. This introduces latency and congestion.

IP Switching

- The idea is to make a connectionless data technology behave something like the circuit-switched network
- The goal is to make intranets and Internet access faster, and to enable the deployment of new voice, video,and graphic applications and services.
- IP switching has two objectives
  - provide a way for internetworks to scale economically
  - provide effective Quality of Service support to IP
  - replace Layer 3 hops with Layer 2 switching
    - hardware-based forwarding performance

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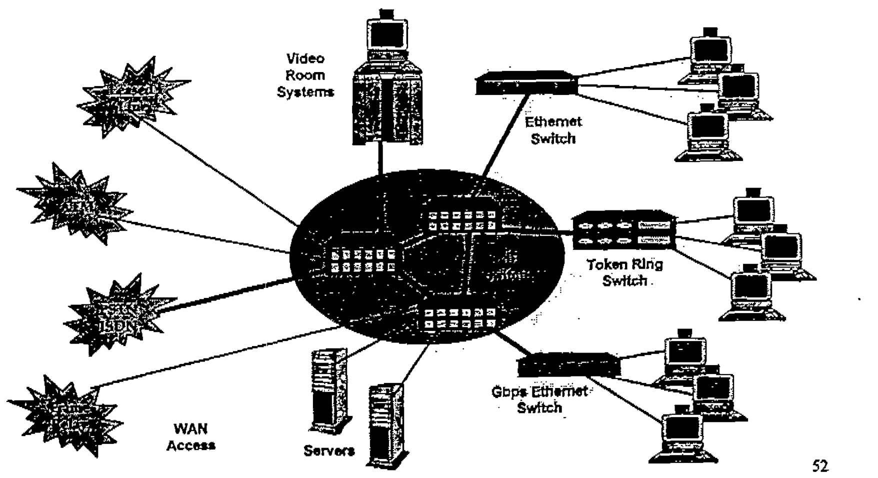
Switched IP Backbone



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ATM Characteristics

- ATM is a high-bandwidth, fast-packet switching and multiplexing technique that allows seamless end-to-end transmission of voice, data, image, and video traffic.
- ATM is a high-capacity, low latency switching fabric adaptable for multiservice and multirate connections.
- ATM switches ranges in capacities from 10-160 Gbps, with new products emerging in the Tbps. IP routers typically offer capacities ranging from 4-60 Gbps, although emerging generations are also promising terabits per second.

ATM Characteristics

- ATM (Asynchronous Transfer Mode)
  - born out of WAN environment
  - connection-oriented
    - provides means to establish a predefined path between source and destination
    - predetermined data paths enable greater control of network resources
    - over-allocation of bandwidth becomes an engineered decision
    - offers more deterministic way to respond to changes in network status

ATM Characteristics

- ATM (Asynchronous Transfer Mode)
  - real-time traffic management allows
    - policing and traffic shaping
    - networkwide resource allocation for class-of-service provisioning
    - deterministic transit delay
    - delay-variation measurement and control
    - multiple QoS levels

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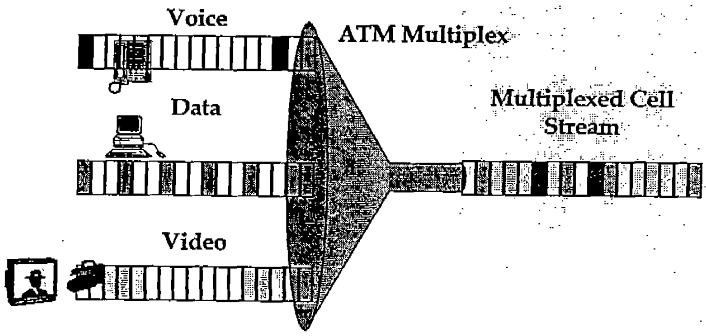
ATM Broadband Service Attributes

- ATM enables access bandwidth to be shared among multiple sources and network resources to be shared among multiple users.
- ATM allows different services to be combined within a single access channel.

LIDO 56

Mapping Services into ATM



ATM Characteristics

- High bandwidth, high performance
- Uniform 53 byte cell
- Connection-oriented network
- Virtual circuit path
- Limited error control procedures
- Asynchronous information access
- Quality of Service definitions

ATM Applications

- Carrier infrastructure
- Frame relay backbone
- Internet backbone
- Multimedia VPNs
- Campus and workgroup networking
- Enterprise network switch
- Residential broadband

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ATM Applications

- Backbone network consolidation
- Frame relay traffic concentration
- Interactive multimedia
- LAN interconnect
- Telephony
- Videoconferencing
- Data warehousing
- Scientific computing
- High-speed Internet access
- Other applications requiring high performance

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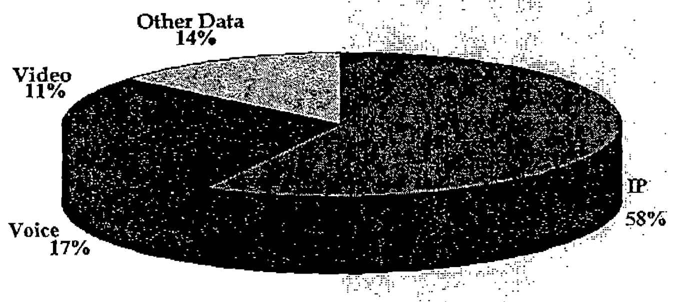
ATM Bandwidth Utilization (U.S.)

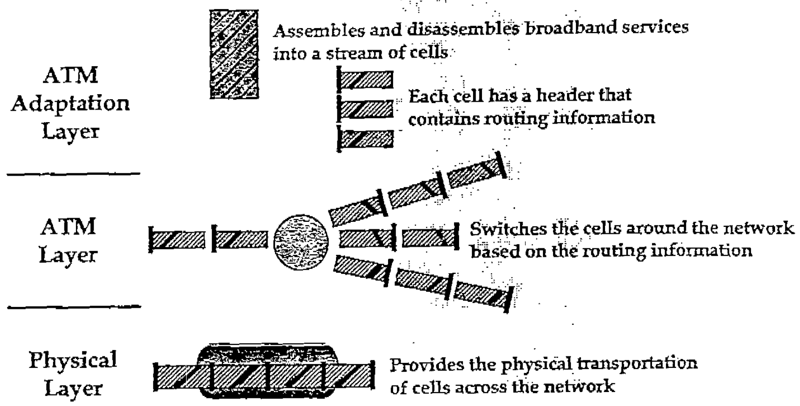


Source: Vertical Systems Group
Broadband Industry Update 9/00

ATM Customers

- Internet Service Providers (ISPs)
- Financial institutions
- Manufacturers
- Health care organizations
- Government entities
- Educational institutions
- Research labs and institutes
- Other enterprises with broadband applications

ATM Layers



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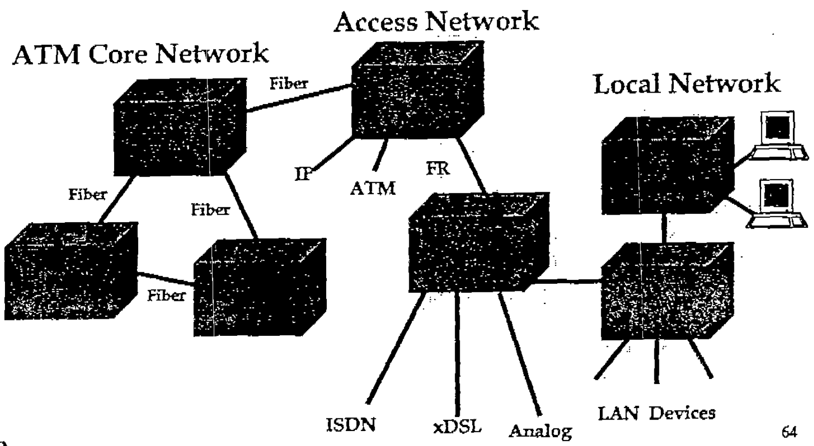
ATM Infrastructure



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ATM Equipment Segments

- ATM switches for carriers, ISPs, and private enterprise networks
- ATM WAN access equipment
- ATM LAN switches
- Equipment providers include 3Com, ADC, Alcatel (Newbridge), Cisco, Lucent, Marconi (Fore), Nortel

ATM Market

- Global market for equipment & services
  - 1999 US$ 5.6 Billion
  - 2002 US$ 13.3 Billion (6.9 billion outside the U.S.)
- Equipment revenues
  - 1998 US$ 3.1 Billion
  - 2002 US$ 9.4 Billion
- Service revenues
  - 2002 US$ 3.9 Billion
    - US accounts for 75% of worldwide revenues, Europe is the second largest market, with the UK accounting for most of the ATM ports. Canada is next biggest market, and Asia-Pacific is the fastest growing.
    - ATM UNI services offered by some 50 providers

Source: Vertical Systems Group Broadband Industry Update 9/00

IP vs ATM

Transport	Upside	Downside	Other services supported	Packet size	Header
IP	Pervasive at the desktop	No Quality of Service	Voice	Variable, 40 bytes to 64,000 bytes	40 bytes
ATM	Multiple service classes	Small cell size inefficient for data transport	Voice, IP, frame, X.25, leased lines	Fixed cells, 53 bytes	5 bytes

IP and ATM

- IP has become the universal language of computer networking, winning the desktop.
- IP-based services being introduced include VPNs, e-commerce, outsourced remote access, application hosting, multicasting, and voice, fax and video over IP.
- Larger pool of knowledgeable programmers for IP than ATM
- These services must support multiple classes of service and QoS, as well as controlled access.
- IP standards for QoS are just being developed
- ATM will be increasingly used to switch IP traffic due to its network management, restoration and reliability capabilities.
- ATM switch market will experience a compound annual growth rate of 36% over the next five years according to Yankee Group

Terabit Switch Routers

- Emerging class of backbone platforms
- Terabits of capacity
  - current products range from 640 Gbps to 19.2 Tbps
  - interfaces range from OC-3 to OC-192
- Agnostic, support for all data traffic types
- Short and predictable delay
- Robust QoS features
- Multicast support
- Carrier class availability
- Looking forward, terabit routers are aiming to integrate with other network elements. The idea is that the terabit router and the optical switch will communicate using MPLS.

Terabit Switch Routers

- Ascend (now Lucent), Avici Systems, Argon Networks (now Unisphere (Seimens)), Charlotte's Web Networks, Cisco, Ironbridge Networks, Juniper Networks, Nexabit (now Lucent), Nortel Networks, Pluris, Netcore (now Tellabs)

Tiered Broadband Backbone

- Access switches
  - outer tier - delivers broadband to customer
    - associated with single user access - analog, ISDN, xDSLs
    - DSLAMs, remote access servers, remote access routers
- Edge switches
  - second tier - protocol & data service integration
    - concentrate traffic and prepare it for backbone
    - voice/data gateways (circuit--to-packet network integration)
    - provide policy-based services management
- Core switches
  - inner tier - handles transmission of ATM, IP or MPLS traffic

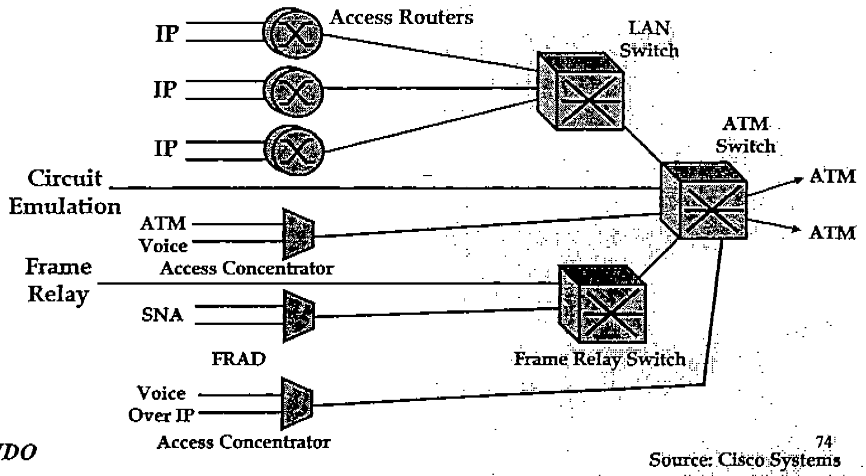
Access Tier

- Access devices include
  - Class 5 local exchanges, digital loop carriers (DLC)
  - DSLAMs (DSL access multiplexer) - designed to concentrate hundreds of xDSL access lines onto ATM or IP trunks and then route them to routers or multiservice edge switches
  - Integrated access devices (IAD)
  - Remote access servers (RAS)- provide access to remote users via analog modem or ISDN connections; includes dial-up protocols and access control (authentication)
  - Remote access routers - used to connect remote sites via private lines or public carries, provides protocol conversion between LAN and WAN

The Intelligent Edge

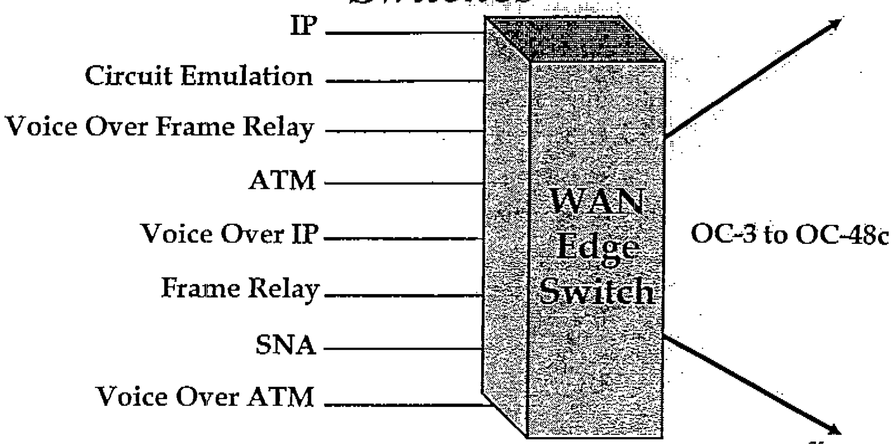
- Edge devices can include
  - next-generation switches, convergence switches, media gateways, VoIP gateways, ATM switches, IP routers, IP switches, multiservice agnostic platforms, collaborating servers
  - network management stations
- Will handle authentication, authorization, and accounting
- Will request specific levels of performance and map the requested service to the core
- Moving closer to customer, extending to the CPE

Complexities With Single Purpose Boxes



Source: Cisco Systems

Simplicity With Multi-Purpose Switches



LIDO

Source: Cisco Systems

The Intelligent Edge

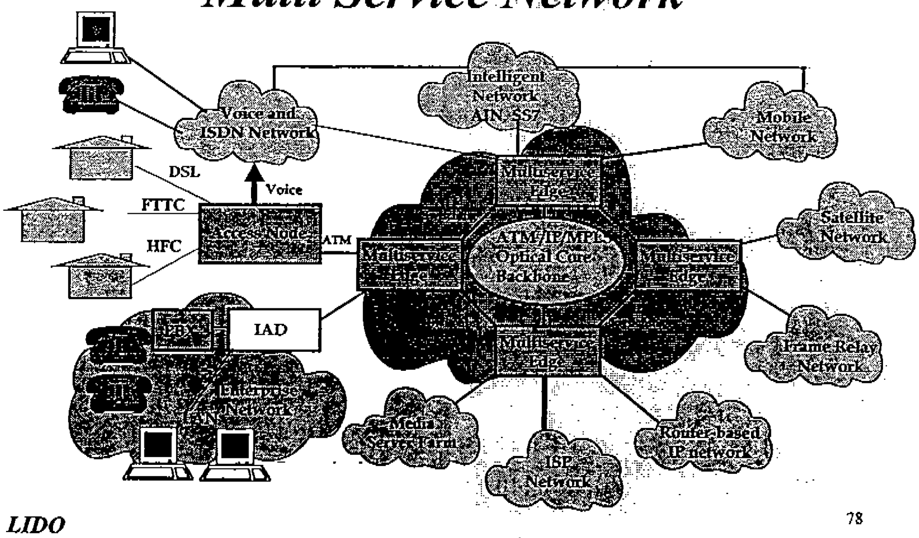
- Main responsibilities include access, adaptation, and concentration
- Point at which service attributes are mapped to QoS mechanisms to deliver requested performance
- Allows rapid service provisioning of services dynamically customized for each individual user
- Service changes can be made without affecting the core

LIDO

The Intelligent Edge

- ◆ Service provisioning that decouples service specification from service delivery
- ◆ Policy engine handles service provisioning
  - ◆ encryption
  - ◆ key or certificate distribution
  - ◆ tunneling
  - ◆ accounting
  - ◆ address allocation
  - ◆ domain name management
  - ◆ QoS

Multi Service Network



Switching the Architecture

- Traditional Class 5 (local exchange) and Class 4 (toll exchange) common control architecture
  - intelligence centralized in proprietary hardware and software
  - make use of Remote Switching Modules (RSMs) and Digital Loop Carriers (DLCs)
  - adjunct boxes for enhanced services
  - separate data network access
  - network operator must wait for generic software releases from manufacturer to launch application/services
  - long time required for application development
  - typical up front cost of US$ 3-5 million per deployment

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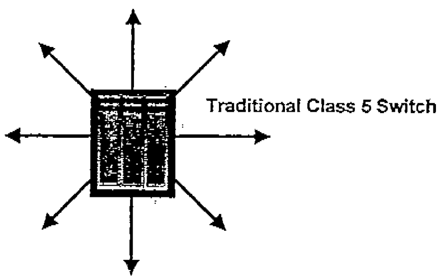
Traditional Common Control Circuit Switched Architecture



•Proprietary hardware & software
•Manufacturer must develop software release to launch application/services
•Service provider married to manufacturer
•Long application development time

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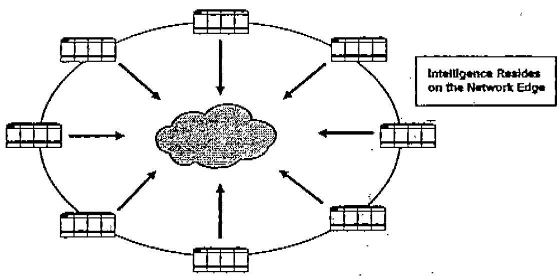
Switching the Architecture

- Next-generation switch architecture
  - intelligence resides on the network edge, distributed control
  - ATM and/or IP core switching and backbone
  - integrated access device (IAD) at customer premise
  - gateway switch provides Class 5 functionality with integrated enhanced services and converged network access
  - switch interfaces with SS7 via SS7 gateway switch
  - more applications can be developed, more revenues can be generated
  - service creation occurs at the network edge, closer to the customer
  - combined benefits of lower cost and faster application development
  - US$100,000 start-up cost

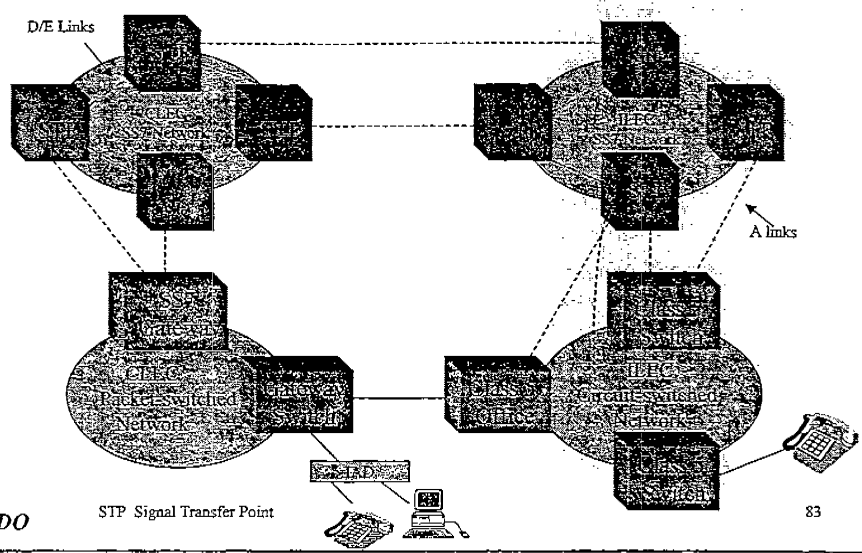
Next-Generation Switch Architecture



•Distributed intelligence
•Service creation at network edge... closer to the customer
•Lower cost, more flexible, faster application development

Source: Telecom Business

Next Generation Gateway Switch

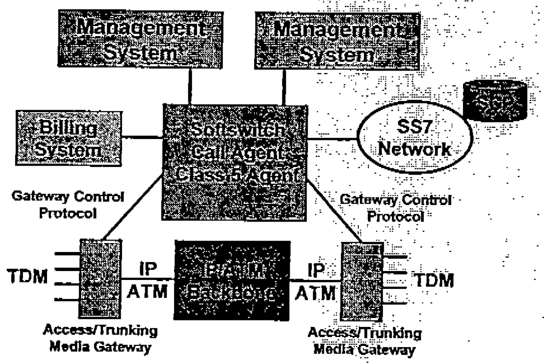


STP Signal Transfer Point

Programmable Networking

- A root system of softswitches and media gateways that will convert different media and protocol types.
- Requires separating the service logic that activates, controls, bills for and manages a particular service from transmission, hardware or signaling nodes.
- Makes call functions easier to manage.
- Will allow providers the chance to offer
  - circuit-switched voice and AIN services, such as caller ID and call waiting
  - packet switched services and applications, such as Internet access, e-mail, Web browsing and e-commerce
  - also embraces wireless networks

Softswitch Model



Source: Bell Labs Technical Journal

Programmable Networking

- The softswitch controls the voice or data traffic path by signaling between media gateways that actually transport the traffic.
  - The gateway provides the connection between an IP or ATM network and the traditional circuit-switched network, acting like a multiprotocol cross-connect.
  - The softswitch ensures that a call or connection's underlying signaling information (automatic number identifiers, billing data, call triggers) gets communicated between gateways.

Programmable Networking

- Softswitches must communicate with packet switches, VoIP gateways, and the SS7 networks using standardized protocols.
- There are a number of different technical specifications, protocols and standards used to deliver these services and the desired end functions.
  - H.323
  - H.GCP
  - SIP
  - SGCP
  - IDPC
  - MGCP
  - Megaco (H.248)

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Programmable Network Protocols

- H.323
  - ITU standard for IP telephony in the LAN
  - used as the basis for several early VoIP gateways
- Session Initiation Protocol (SIP)
  - links end devices and IP media gateways
  - a thinner and less robust version of H.323
- H.GCP
  - ITU extension of H.323 to enable IP gateways to work with SS7
- Simple Gateway Control Protocol (SGCP)
  - defined by Cisco and Telcordia
  - forerunner to MCGP

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Programmable Network Protocols

- Internet Protocol Device Control (IPDC)
  - defined by Level 3
  - forerunner to MGCP
- Media Gateway Control Protocol
  - controls transport layer and its various media gateways; sends messages about routing, priority and quality
- Megaco (H.248)
  - An emerging ITU standard that describes how the media gateway should behave and function

Programmable Networking

- Key concerns for providers include
  - scalability
    - current products can scale up to a threshold of 200,000 busy-hour call attempts (BHCA)
      - Class 5 local exchanges handle 1.5 million plus BHCA
      - Class 5 local exchanges offer 3000 plus features
    - clustering software can help scale
  - reliability
  - a secure way to interact with intelligence at the customer premises
- Yankee Group predicts softswitch sales will reach US$ 631 million and top US$4.3 billion by 2004.

Quality of Service

- Ability to provide different levels of service to differently characterized traffic or traffic flows
- Basis for offering various classes of service to different segments of end users
- This allows the creation of different pricing tiers that correspond to the QoS level
- Needed to deploy voice or video services with data
- QoS definitions include
  - network bandwidth
  - user priority control
  - controlling packet/cell loss
  - controlling network traffic transit delay (end-to-end)
  - controlling network traffic delay variation (jitter)

Quality of Service Characteristics

- Traffic Characterizations
  - delay tolerance and elasticity
  - associated applications and users
  - time of day
- Levels of Service
  - guarantees (achieved bandwidth, delay, delay variance, packet loss)
  - relative priority
- Associated policy, admission control and policing
- Implicit QoS - the application picks the QoS
- Explicit QoS - network manager controls QoS

Network QoS

- Three main approaches
  - architected QoS
    - ATM
  - per flow services
    - RSVP (IETF IntServ), MPLS
  - packet labeling
    - 802.1p, IETF DiffServ

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ATM QoS

- ATM QoS defines a series of specific quality-of-service parameters that tailor cells to fit video, data, voice, and mixed-media traffic.
- ATM architecture defines five service classes.
  - Constant bit rate (CBR) - provides constant, guaranteed rate to realtime applications like streaming video
  - Variable bit rate (VBR) - provides fair share of available bandwidth according to a specific allocation policy
    - realtime and non-realtime
  - Available bit rate (ABR) - supports variable bit-rate data traffic with average and peak traffic parameters
  - Unspecified bit rate (UBR) - best effort, does not specify traffic-related service guarantees

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ATM Service Class Applications

- Constant Bit Rate (CBR)
  - videoconferencing; interactive audio, audio/video distribution, audio/video retrieval
- Variable Bit Rate (VBR)
  - Real-time VBR can be used by native ATM voice with bandwidth compression and silence suppression. It is also appropriate for multimedia.
  - Non-real-time VBR can be used for data transfer, such as response time critical transaction processing applications like airline reservations, banking transactions and process monitoring, and frame relay interworking

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ATM Service Class Applications

- Available Bit Rate (ABR)
  - LAN interconnection/internetworking services, LAN emulation, critical data transfer (defense information, banking services), supercomputer applications and data communications like remote procedure call, distributed file services and computer process swapping/paging.
- Unspecified Bit Rate (UBR)
  - text/data/image transfer, messaging, distribution, retrieval and remote terminal (telecommuting).

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ATM Classes of Service

Parameter	CBR	VBR-NRT	VBR-RT	ABR	UBR
CLR	yes	yes	yes	no	no
CTD	yes	yes	yes	no	no
CDV	yes	no	yes	no	no
PCR	yes	yes	yes	yes	yes
SCR	no	yes	yes	no	no
BT	no	yes	yes	no	no
Flow Control	no	no	no	yes	no

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ATM Technical Parameters

- Quality of Service Parameters

- CER Cell error rate
  - % errored cells
- CLR Cell loss ratio
  - % cells lost
- CTD Cell transfer delay
  - delay between network entry and exit points
- CDV Cell delay variation
  - variance of CTD

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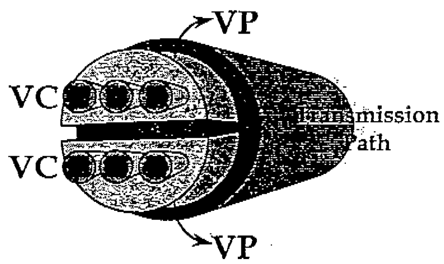
ATM Technical Parameters

◆Traffic Parameters

- ◆ PCR Peak cell rate
  - ◆ maximum cell rate
- ◆ SCR Sustained cell rate
  - ◆ average cell rate
- ◆ MCR Minimum cell rate
  - ◆ minimum traffic rate
- ◆ BT Burst Tolerance
  - ◆ maximum burst at peak rate

Relationship of VP, VC and Transmission Path



VC = Virtual Channel
VP = Virtual Path

ATM's Cell Structure

BYTE	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1
0	Generic Flow Control				Virtual Path Identifier			
1	Virtual Path Identifier				Virtual Channel Identifier			
2	Virtual Channel Identifier							
3	Virtual Channel Identifier				Payload Type			Cell-loss Priority
4	Header Error Control							
5-52	Payload							

Integrated Services Architecture

- Integrated Services Architecture (IntServ)
  - IETF scheme to introduce QoS support over IP networks.
  - Provides extensions to the best-effort service model to allow control over end-to-end packet delays.
  - Key building blocks include resource reservation and admission control.
  - IntServ, a per flow resource reservation model, requires RSVP (Resource Reservation Protocol)
  - RSVP allows applications to reserve router bandwidth.
  - RSVP guaranteed service provides bandwidth guarantee and reliable upper bound to packet delay
  - The resource requirements for running RSVP on a router increase proportionally with the number of separate RSVP reservations. This scalability problem makes using RSVP on the public Internet impractical.

Differentiated Services

- Differentiated Services (DiffServ)
  - evolved from IETF IntServ, DiffServ is a prioritization model, with preferential allocation of resources based on traffic classification.
  - DiffServ uses the IP TOS (Type of Service) field to carry information about IP packet service requirements.
  - Classify traffic by marking IP header at ingress to network with flags corresponding to small number of "per hop behaviors"
    - DiffServ DS-byte replaces TOS octet, sort into queues via this DS flag
    - Queues get different treatment (priority, share of bandwidth, probability of discard)
- IETF draft stipulates a MIB (Management Information Base) for DiffServ, which will make DiffServ-compliant products SNMP-manageable

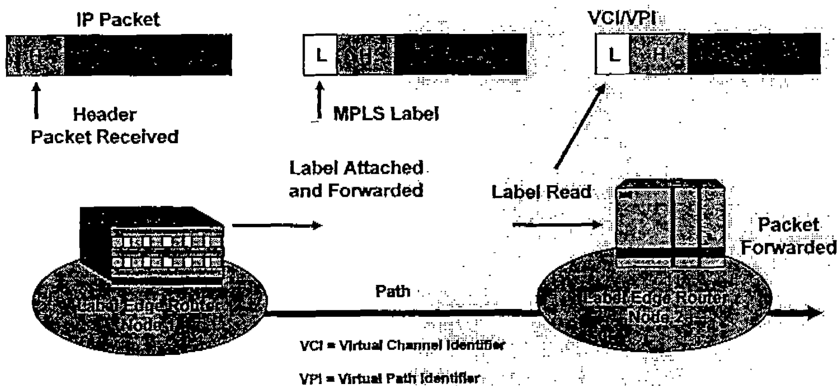
Class-Based Queuing (CBQ)

- CBQ is based on a traffic management algorithm deployed at the WAN edge.
  - Allows traffic to be prioritized according to IP application type, IP address, protocol type, and other variables.
  - Allocates unused bandwidth more effectively than other QoS mechanisms
  - Uses priority tables to give critical applications the most immediate access to unused bandwidth.

Multiprotocol Label Switching (MPLS)

- Multiprotocol Label Switching (MPLS)
  - from the Internet Engineering Task Force (IETF), born of Cisco's tag switching, designed with large-scale WAN in mind
  - tags or adds a label to IPv4 packets so they can be steered over the Internet along predefined routes.
  - adds a label identifying the type of traffic, path and destination
  - allows routers to assign explicit paths to various classes of traffic

How MPLS Works



Source: General DataComm

How MPLS Works

- With MPLS you can support all applications on an IP network without having to run large subsets of the network with completely different transport mechanisms, routing protocols, and addressing plans.
- Offers the advantages of circuit-switching technology, including bandwidth reservation and minimized delay variations for voice and video traffic, plus all the advantages of existing best-effort, hop-by-hop routing.

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How MPLS Works

- "MP" means it is multiprotocol. MPLS is an encapsulating protocol, it can transport a multitude of other protocols.
- "LS" indicates that the protocols being transported are encapsulated with a label that is swapped at each hop.
  - A label is a number that uniquely identifies a set of data flows on a particular link or within a particular logical link.
  - The labels are of local significance only – they must change as packets follow a path – hence the "switching" part of MPLS.

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How MPLS Works

- MPLS can switch a frame from any kind of layer-2 link to any other kind of layer-2 link without depending on any particular control protocol.
- ATM can only switch to and from ATM and can use only ATM signaling protocols, such as PNNI (Private Network-to-Network Interface) and IISP (Interim Interface Signaling Protocol).

MPLS Labels

- MPLS supports three different types of label formats.
  - On ATM hardware it uses the well-defined Virtual Channel Identifier (VCI) and Virtual Path Identifier (VPI) labels.
  - On frame relay hardware, it uses a Data Link Connection Identifier (DLCI) label.
  - Elsewhere, MPLS uses a new, generic label known as a Shim, which sits between layers 2 and 3.
- Because MPLS allows the creation of new label formats without requiring change in routing protocols, extending technology to new optical transport and switching should be straightforward.

MPLS Evolution

- Major efforts are underway to adapt the control plane of MPLS (e.g., OSPF, IS-IS, LDP, etc) to direct the routing of optical switches, not just LSRs (label switched routers).
- This will allow optical switches, LSRs and regular IP routers to recognize each other.
- The same routing system can control optical paths in the DWDM core, LSPs (label switched paths) across the MPLS backbone and any IP routers at the edge of the network.

Policy-based Management

- The idea behind policy-based networking is to associate information about individual users, groups, organizational units, entire organizations and even events (such as the beginning of the accounting department's month-end closing) with various network services or classes of service.

Common Open Policy Service

- Common Open Policy Service (COPS)
  - An IETF query-response-based client/server protocol for supporting policy control
  - Addresses how servers and clients on a network exchange policy information.
  - Transmits information between a policy server and its clients, which are policy-aware devices such as switches.
  - Main benefit of COPS is that it will create more efficient communication between policy servers and policy-aware devices, and increase interoperability among different vendors' systems

Directory Enabled Networking

- DEN is an industry group formed by Microsoft and Cisco to create a common data format for storing information about users, devices, servers, and applications in a common repository.
- DEN describes mechanisms that will enable equipment such as switches and routers to access and use directory information to implement policy-based networking. Enterprise directories will eventually be able to represent, as directory objects, all of the following
  - network elements (switches, routers)
  - network services (security, CoS)
  - network configurations that implement these services
  - policy services that govern them in a coordinated, scalable manner

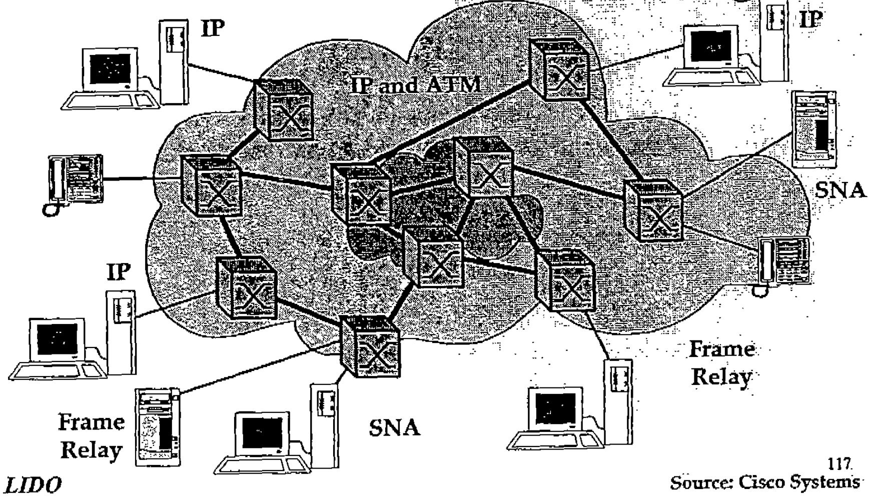
Lightweight Directory Access Protocol (LDAP)

- Standard directory server technology for the Internet.
- Directory servers will know when to tell network devices to prioritize traffic from certain people, organizations and applications.
- Lightweight Directory Access Protocol (LDAP) allows retrieval of information from multivendor directories. LDAP 3.0 provides client systems (hubs, switches, routers) a standard interface to read and write directory information
- Equipment and directory vendors plan to use LDAP for accessing and updating directory information.

Tiered Broadband Backbone

- ◆Core switches
  - ◆designed to be incredibly big, incredibly fast, and sometimes dumb
  - ◆designed to transport traffic reliably at the highest available rate
- ◆Access and Edge switches
  - ◆designed to be scalable in port count and to deliver multiservice support
  - ◆evolving to include intelligent features & policy-based services management

Network Core Serves The Edges



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Source: Cisco Systems

Optical Networking

Element	*Year Introduced*
• Fiber Optics	1970
• SDH/SONET	1988
• EDFA	1994
• Wavelength division multiplexing	1996
• Dense WDM (DWDM)	1998
• Optical add/drop multiplexers	1999
• Optical cross-connects	1999-2000
• Optical switches	2000
• True optical switches	2003-2005

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Erbium Doped Fiber Amplifiers (EDFA)

- Introduced in 1994, EDFA's were a key innovation, made up of erbium metal doped with special atoms, incorporated in an optical fiber at periodic intervals (normally every 30-60 miles) to pump the communications signal.
- Before EDFA's, electronic regenerators had to extract signals, retime them, then regenerate them, limiting data rates to 2.5 Gbps.
- EDFAs opened the way for the development of wavelength division multiplexing (WDM).

Fiber Optics Transmission

- Fiber optic cables
  - Multimode
    - Suffers from modal dispersion, requires more frequent repeaters, easier termination
  - single mode
    - No modal dispersion, good signal quality over longer distances, more difficult to terminate
- Light sources
  - LEDs
    - Couples less light into fiber, lower data rates, lower cost
  - laser diodes
    - Purer light source, less distortion, higher data rates, higher cost

Synchronous Digital Hierarchy (SDH)
Synchronous Optical Network (SONET)

- Industry standard for high-speed transmission over optical fiber.
- Introduced in late 1980's, origins in Broadband ISDN
- According to the ITU-T, SDH/SONET is a family of transmission standards for achieving compatibility of fiber optic transport products and the existing digital hierarchy.
- SDH/SONET provides the physical layer framework, standardizing optical parameters, data rates, multiplexing, and operations capabilities.

SDH/SONET Signal Hierarchy

OC LEVEL	SONET	SDH	DATA RATE (Mbps)	PAYLOAD RATE (Mbps)
OC-1	STS-1	STM-0	51.48	50.840
OC-3	STS-3	STM-1	155.52	150.336
OC-9	STS-9	STM-3	466.56	451.008
OC-12	STS-12	STM-4	622.08	601.344
OC-18	STS-18	STM-6	933.12	902.016
OC-24	STS-24	STM-8	1244.16	1202.688
OC-36	STS-36	STM-12	1866.00	1804.032
OC-48	STS-48	STM-16	2488.32	2405.376
OC-96	STS-96	STM-32	4876.64	4810.752
OC-192	STS-192	STM-64	9953.28	9621.504

STS - Synchronous Transport Signal STM - Synchronous Transport Module
OC - Optical Carrier

SDH / SONET Signal Hierarchy

- Signals below DS3 are mapped into Virtual Containers (SDH terminology) or Virtual Tributaries (SONET terminology)
  - defines a data structure for the transport and switching of sub-STS-1 network services such as DS1, CEPT1, DS1C and DS2.

VC/VT Level	Line Rate	Standard
VC-11/VT1.5	1.728 Mbps	DS1/E1
VC-2/VT2	2.304 Mbps	E1
VT3	3.456 Mbps	DS1C
VC-2/VT6	6.912 Mbps	DS2
VT6-N	Nx6.9 Mbps	future
async DS3/VC3	44.736/34.368 Mbps	DS3/E3
VC-4	139.264 Mbps	DS4/E4

SDH/SONET Functions

- SDH/SONET specifications define
  - a frame format, a physical interface, optical carrier line rates, and an operations, administration, maintenance and provisioning protocol.
  - SDH/SONET also introduced ring operations, addressing network survivability
- SDH/SONET grooms and routes traffic
  - grooming is the selective removal of channels from a digital facility for routing to a designated remote location via another digital facility.
- Provides performance monitoring
- Handles restoration

SDH/SONET Infrastructure

- Fiber optic transmission media
- Regenerators or EDFAs
- Terminal Multiplexers (TM)
- Add-drop Multiplexers (ADM)
- Wideband Digital Crossconnect (WDCS)
- Broadband Digital Crossconnect (BDCS)
- Digital Loop Carrier
- SDH/SONET CPE

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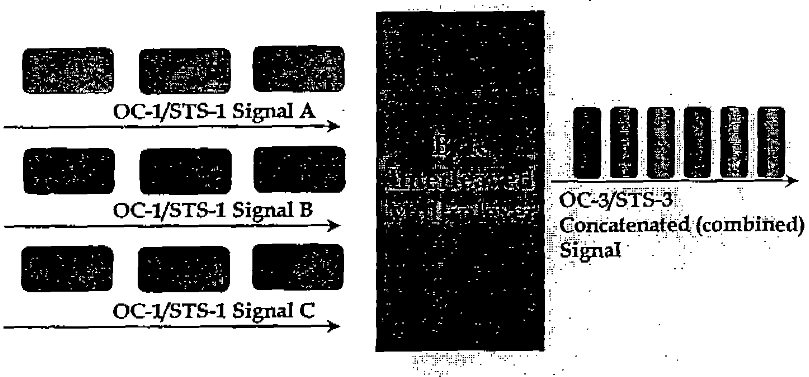
Terminal Multiplexing (SONET example)



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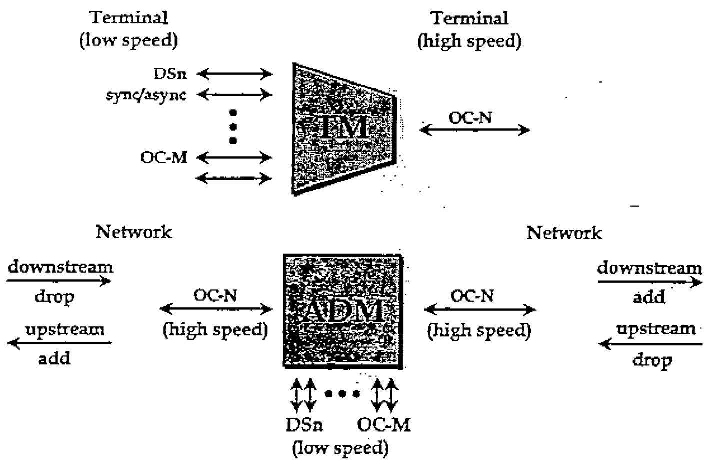
SDH/SONET Multiplexers

- Terminal multiplexers
  - Act as access nodes, supporting current services by accepting electrical interfaces (DS1/E1, DS1C, DS2, DS3/E3)
  - Concentrates one or more OC-n signals
- Add-drop multiplexers (ADM)
  - Building blocks of the SDH/SONET network
  - Convert one or more DS-n signals into/from an OC-n signal
  - Can drop lower-rate signals to be transported on different facilities, or can add lower-rate signals into the higher-rate OC-n signal
  - Allow telcos to add and drop traffic along a network.

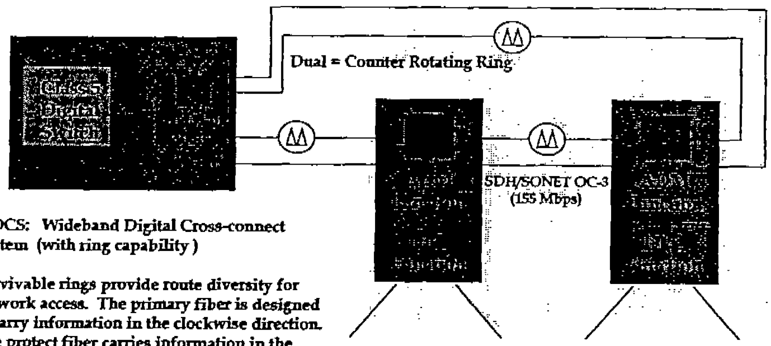
TM vs ADM



SDH/SONET Crossconnects

- Wideband digital crossconnect (WDCS)
  - Terminates SDH/SONET and DS3 signals, switching at the DS0, DS1/E1, or VT level.
  - Optical equivalent to the DS3/DS1 or E3/E1 digital crossconnect.
- Broadband digital crossconnect (BDCS)
  - Interfaces various SDH/SONET signals and legacy DS3/E3s, switching at the STS-1 level
  - Can make crossconnections at the DS3/E3, STS-1, and STS-c (concatenated) levels
  - Generally used as SDH/SONET hub that grooms STS-1s for broadband restoration purposes or for routing traffic

SDH/SONET Ring



WDCS: Wideband Digital Cross-connect System (with ring capability)

Survivable rings provide route diversity for network access. The primary fiber is designed to carry information in the clockwise direction. The protect fiber carries information in the counter clockwise direction.

SDH/SONET Benefits

- Tremendous speeds
- Standardization of physical interfaces
- Reduced cost for provisioning digital circuits
- End-to-end monitoring potential, but interoperability at the network management level remains an issue
- Self-healing architecture
- SDH/Sonet's reliability will keep it in the network infrastructure for 10-15 years

SDH/SONET Future

- SDH/SONET main functions will have to be incorporated in other network devices before it exits the network
  - link-based performance monitoring
  - fully redundant routing capabilities
  - management capabilities
  - provisioning and multiplexing
  - operations support systems (OSS) compatibility

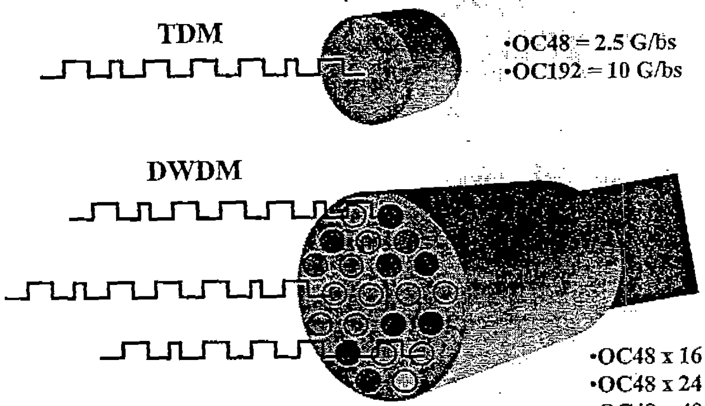
SDH/SONET Future

- SDH and SONET equipment revenues for 1997 reached US$3.7 billion, predicted to peak at about US$10 billion by 2001
  (Ryan, Hankin and Kent)
- Revenues are forecast to begin declining after 2001 due to price reductions, slower network expansion, increasing use of other broadband technologies such as DWDM and the continued move towards end-to-end optical networking.

Wavelength Division Multiplexing

- Current fiber optic systems use only a fraction of the available bandwidth
- WDM takes advantage of the fact that multiple color (frequencies) of light can be transmitted simultaneously down a single optical fiber
- The data rate supported by each wavelength depends on the type of light source
  - today it ranges from 2.5 Gbps (OC-48) to 10 Gbps (OC-192) to 40 Gbps (OC-768) per wavelength
  - Tbps light sources are expected in 2000
  - lasers operating in femtoseconds expected in five years
    - this means that the time between bursts is the same that light (traveling at 186,000 miles per second) takes to travel the width of a human hair

Dense Wavelength Division Multiplexing (DWDM)



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Dense Wavelength Division Multiplexing (DWDM)

- WDM furnishes separate channels for each service at the full rate
  - Cannot aggregate smaller channels into one large channel
- Systems supporting more than sixteen wavelengths are referred to as DWDM (dense wavelength division multiplexing)
  - OC-48 (2.5 Gbps) systems today support 16-128 channels
  - OC-192 (10 Gbps) systems currently supporting 8-32 wavelengths
  - Nortel Networks introducing system operating 80 wavelengths at 80 Gbps per wavelength
  - The potential exists for transmitting 15,000 channels on a single fiber, developments include Bell Labs "chirped pulse" WDM

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DWDM Potential

- Bell Labs developing "chirped pulse" WDM
  - idea revolves around a specialized "mode-locked laser" which will rapidly emit very wide pulses of light.
    - Since each part of a fiber interacts differently with varying frequencies of light, the result is unequal dispersion. In summary, the pulse is "stretched out" once it enters the fiber, and data can be put on the discrete frequencies that emerge.
    - Horse race analogy - when a race starts, horses emerge together from the gate. Since each horse keeps its own pace, spaces will soon develop among them. This is the same "stretching out" that happens to the laser light. (Wayne Knox, Bell Labs, tele.com 1/00)

Dense Wavelength Division Multiplexing (DWDM)

- Key DWDM vendors include
  - Alcatel, Alidian, Astral Point, Cambrian (now Nortel), Cerent, Chorum Technologies, Chromatis Networks, Ciena, Corvis, Ericsson, JDS Uniphase, Lightera (now Ciena), Lightwave Microsystems, Lucent, Monterey Networks (now Cisco), NEC, Nortel Networks, Optical Networks, Osicom Technologies, Pirelli, Sycamore Networks, Wavesplitter
  - According to Ryan Hankin & Kent estimates, the worldwide DWDM market grew to US$4 billion in 1999.

DWDM Deployments

- AT&T expects DWDM technology will allow the capacity of the network to grow by a factor of 10.
- Sprint anticipates upgrading its fiber backbone with DWDM by a factor of 17 by the year 2000.
  - A single Sprint fiber, in 1998, can carry 2 million calls simultaneously - the equivalent of the combined peak time voice traffic of Sprint, AT&T and MCI. By the year 2000, one fiber will have the capacity to carry 34 million calls simultaneously.
    - The Oncoming Glut of Bandwidth, BCR August 1998

DWDM Challenges

- While TDM is reaching its limits in terms of network elements and switching technologies, WDM is just beginning.
  - Obstacles include management and performance impedance mismatches between networks
  - Interoperability standards under development
    - ITU-T study group 15/WP4 Q.25

DWDM Developments

- DWDM is beginning to be able to address quality of service (QoS) requirements
- DWDM is now capable of highly valued SDH/SONET like capabilities
  - monitoring performance
  - providing protection and provisioning optical channels

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DWDM in the Core

- The core network was the first place to deploy DWDM. Increases in intercity traffic required carriers to expand the capacity of their long-haul pipes
  - Response was to deploy point-to-point links running WDM/DWDM
    - Resolves the bandwidth problem, but does not address routing
    - WDM/DWDM currently lacks the intelligence to deliver meshed network configurations, thus the need for optical switches
  - DWDM in the core reduces deployment costs.
    - Eliminates the need for expensive amplifiers
    - Current products can operate successfully over 500-700 km. Qtera (now Nortel) promises a 2500km range.

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DWDM in the MAN

- Metropolitan Area Networks (MANs) are also becoming saturated due to the explosion of bandwidth in the local loop
  - Network expansion is costly
    - Pulling fiber along existing conduits costs $30,000 per mile (BankBoston Robertson Stephens study)
- Traditional DWDM systems are not well suited to the MAN
  - Designed to work well on point-to-point inks
  - MAN traffic must be dropped frequently
  - Does not present the same cost justifications as DWDM in the core. The great cost savings DWDM brings to long-haul is the reduction in the need for expensive amplifiers. The MAN is shorter by definition, so there is no need to use expensive amplifiers.
    - $20,000-$30,000 more for an amplifier capable of operating over 500-700 km
    - Runs in MANs are typically no longer than 120 km

DWDM in the MAN

- Next generation metro products are being designed to address the metro core, metro access, and the enterprise.
- Issues the same across all of them
  - Pricing
  - Scalability
  - Access
  - Flexibility

DWDM in the MAN

- Core products are focused on building out citywide rings
  - Generally support longer distances and greater capacity than the access products
- Access products focus on reducing deployment costs.
- Enterprise products address building high-capacity campus networks

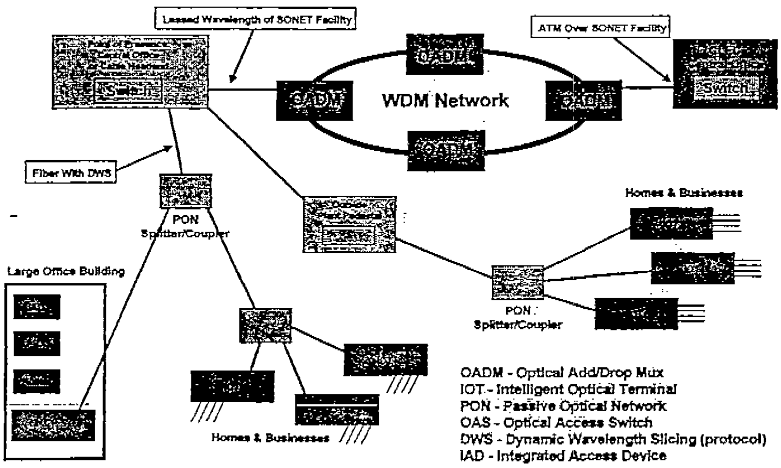
DWDM in the MAN

- Pricing and scalability Issues
  - Lower carrying capacity and distance requirements in the MAN can allow providers to reduce costs by using cheaper lasers
    - Price of transponder boards, representing 90% of the cost of a laser, can vary by 25% depending on the quality of the laser
    - Shorter distance allows less expensive modulation and amplification techniques
      - Long-haul lasers are externally modulated, enabling the signal to travel up to 700 km
      - Shorter distances may allow direct modulation, where the laser runs only about 80-100 km, but cost 30-40% less
    - Cheaper lasers mean less capacity
      - Require greater spacing between wavelengths, may reduce the number of channels by 50%

DWDM in the MAN

- Pricing and scalability issues (continued)
  - Eliminating the active components in the optical network can produce an even more cost-effective network.
  - Passive Optical Networking (PON)
    - Reduces costs by distributing costs across more endpoints and replacing expensive add-drop multiplexers or DWDM nodes with optical splitters and couplers at each fiber connection in the network.
    - Eliminating active components reduces the distance the signal can travel
      - According to Vertical Systems Group, in the US 76% of midsize businesses are within one mile of fiber.
  - Result is a tenfold (10x) savings over conventional SDH/SONET equipment, and even more over DWDM systems.

Passive Optical Network



Source: Quantum Bridge

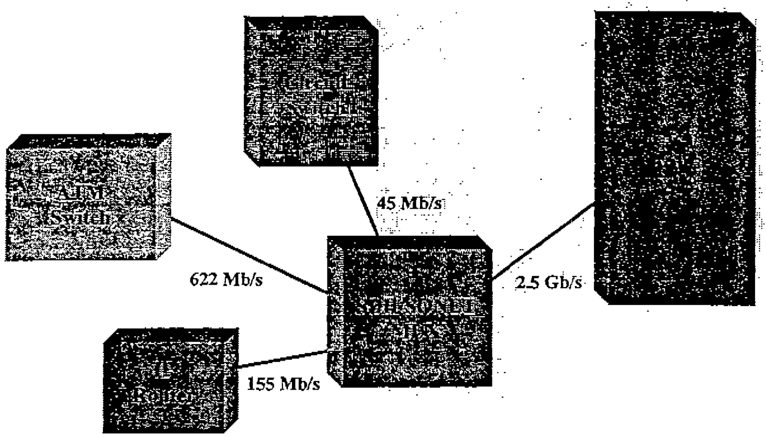
DWDM at the Enterprise

- There are two major bandwidth drivers pushing for delivery of high-speed optics down to the customer premises
  - Customers are looking to connect their data centers through highspeed mainframe interfaces, such as Enterprise Systems Connection (ESCON) and Fiber Channel
  - The Internet – along with generating a huge demand for capacity, changes how traffic flows
    - Old 80/20 rule is reversing – today 80% of US traffic is going between the top 25 cities (Qwest)
    - Traffic patterns shift rapidly, difficult to predict
    - Requires a dynamic network with the ability to accommodate huge capacity requirements

DWDM Evolution

- The public switched telephone network was not built to be dynamic
  - Based on a system of 64 Kbps channels (DS0s) aggregated by Time Division Multiplexers (TDMs) into DS1/E1 (1.544/2.048 Mbps) or DS3/E3 (45/34 Mbps) which deliver traffic into cross-connects and switches at the network core.
  - More TDMs are required at the other end, to reverse the process and distribute the DS0s.
  - TDMs are expensive, and often require manual configuration, slowing down provisioning and further increasing costs.

SDH/Sonet to DWDM



Source: Ciena Corp.

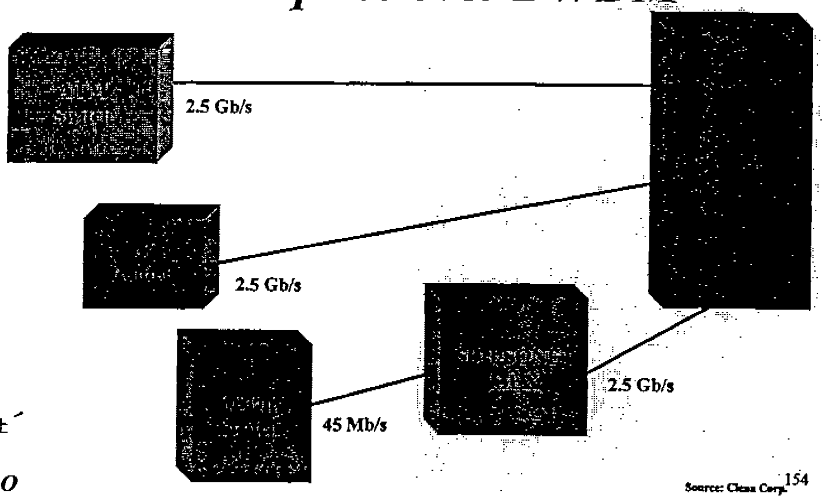
Enterprise DWDM

- Subscribers want to connect at the current speed of their backbone.
- They want to make a direct connection through metro and long-haul networks, with the associated protocols.
- Carriers can no longer expect customers to cover the cost of running data over their networks.
  - Requiring customers to pay for protocol conversion or aggregation equipment
- Customers want guaranteed QoS

IP over DWDM

- Bandwidth reservation and intelligent IP switches can prioritize voice and video traffic to ensure that high-priority traffic gets the first shot at the underlying bandwidth.
- New generations of IP-based switches provide the capability to meet QoS commitments
  - Layer 3/Layer 4 switching services allow the switch to prioritize and guarantee packets based on pre-determined criteria within a switch, and higher-layer protocols, such as IETF's RSVP, can reserve bandwidth across an entire network.

Enterprise over DWDM



⁂± ´ ± ´

Source: Ciena Corp.

IP over DWDM

- This creates a value proposition for the service provider: it can deliver higher bandwidth, in a format the user want for less cost, while approximating the QoS guarantees the end user expects for high priority traffic.
- With IP based systems a carrier can use statistical multiplexing to oversubscribe its network bandwidth, up to four, five or even 10 times the network's aggregate capability.

IP over Optical Standards

- Two standards efforts would link IP services directly to the optical networks that carry data, allowing these networks to take advantage of the routing intelligence now embedded in IP headers.
  - IETF's Multiprotocol Lambda Switching (MPLmS) initiative
    - supported by UUNet and Cisco
  - Optical Domain Service Interconnection coalition
    - group of smaller optical equipment manufacturers and service providers

IP over Optical Standards

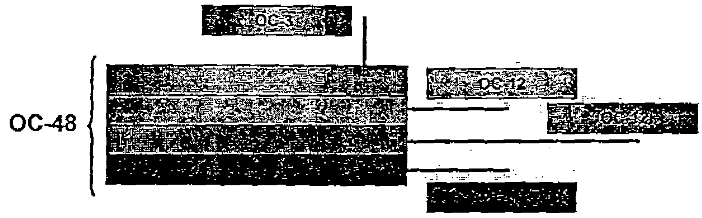
- MPLmS
  - uses labels with packet-forwarding information
  - labels attached to IP packets by a label edge router that sits at the edge of the optical network
- Optical Domain Service Interconnection
  - plans to create open interfaces and signaling protocols, as well as extensions to the MPLS standard for electronic networks
- There is concern that the existence of two standards could lead to the potential development of two technologies in this area

Managed Wavelength Services

- Emerging DWDM application addresses the growing demand for wavelength-on-demand
- Individual wavelengths are assigned either to specific protocols, such as ATM or IP, or to specific customers.
  - Alternatively some providers lease an entire dark fiber to each client, and the client then purchases the CPE to route different protocols over each individual wavelength
- Opening the door to a new way of thinking about providing wavelengths
  - to long-haul carriers, to the metro market, and to customers

Managed Wavelength Services

Customers Manage Their Own Slice



LIDO

Source: Williams

Managed Wavelength Services

- The development of managed wavelength services depends on the development of wavelength changers and optical crossconnects (OXC)
- Wavelength changers convert an optical signal to an electronic signal and then send it to a laser that will produce an optical signal at a different wavelength than the original.
- OXCs give the carriers the the ability to provision bandwidth automatically instead of deploying technicians into the field.
- OXCs allow service providers to build mesh optical restoration which gives them the flexibility of running different kinds of restoration in their networks.
- OXCs allow service providers to establish quality of service levels associated with restoration.

LIDO

Optical Networking

- With transmission rates reaching the Tbps range, the bottleneck moves to the network elements
- To take full advantage of the capacity created by WDM, these fiber networks will need switches capable of rerouting light.
- The cost of optical components was down by 40% in 1998 and was expected to drop another 40% in 1999.
- Switches designed to work directly with light are beginning to emerge

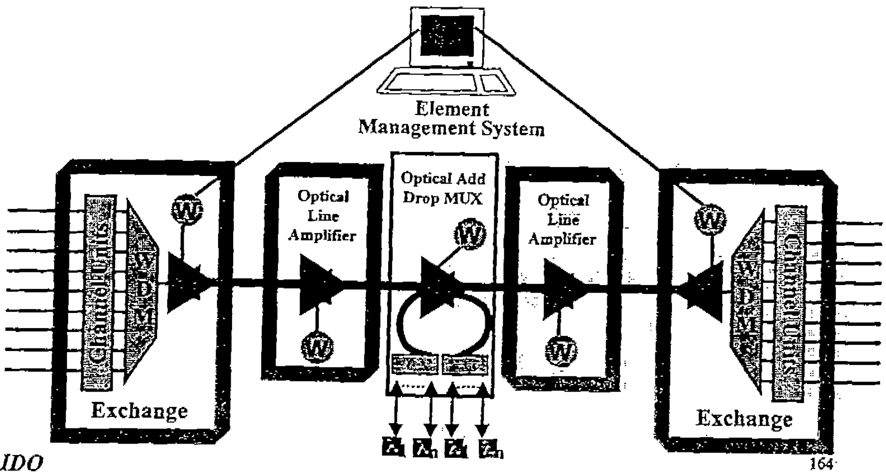
Optical Networking

- Optical switches enable improved reliability, improved scalability, and flexible service provisioning.
- Another major benefit of optical networking is that it reduces the capital required to add additional capacity, and the overall savings can be passed down to the customer.
- Deploying optical networking technology in the MAN can bring the benefits of converged networks down to the customer premises.
- The end-to-end optical infrastructure can support advanced services such as bandwidth on demand.

Optical Networking

- Biggest problem converged telcos face is accurately forecasting future bandwidth needs
  - transmission speeds are reported to be doubling every nine months (Telephony 9/27/99)
  - infrastructures with the ability to provide a large amount of bandwidth on short notice, and at a reasonable cost, are essential
  - without intelligent optical networking, adding an OC-48 circuit over existing dark fiber can take between six and nine months

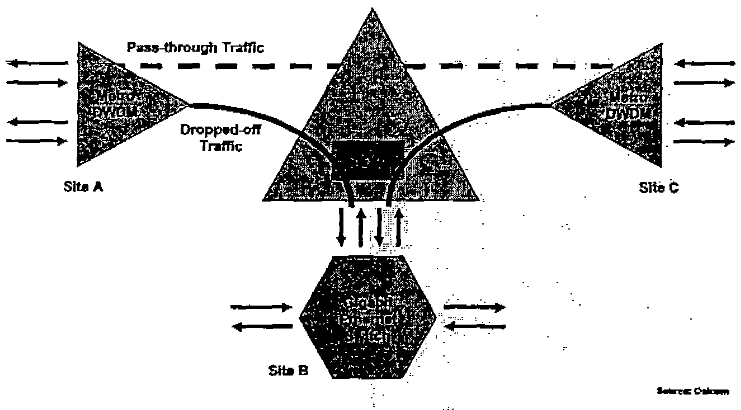
Optical Network



Optical Add/Drop Multiplexers

- Optical add/drop multiplexers (OADM)
  - Next generation networks services must be easily reconfigurable – real-time provisioning
  - Demultiplexing all of the wavelengths at each node would be too costly, would introduce delay, and would reduce the length the signal could travel
  - OADMs will work far more cheaply because they simplify the process by eliminating the costly electronics now used to convert between light and electricity
  - Most products use special filters to extract just the wavelengths they need to be dropped at a given location.
    - For most vendors, that wavelength is fixed – at time of configuration, the carrier would designate the individual wavelengths to be dropped at each location
    - Exception is Optical Networks – relies on Dynamic Transport System (DTS) to dynamically drop wavelengths at any location on a ring

Optical Add/Drop Multiplexing



Optical Crossconnects (OXC)

- Also referred to as optical switches or routers
  - Will link any of several incoming lines to any of several outgoing lines and automatically reroute traffic when a network path has failed
  - Optical version of the general-purpose switching system that provides flexibility and reliability in today's network
  - Optical crossconnects move transmissions between fiber segments and also enable some network management activities such as optical-layer restoration and reconfiguration, dynamic wavelength management, and automated optical-layer provisioning.

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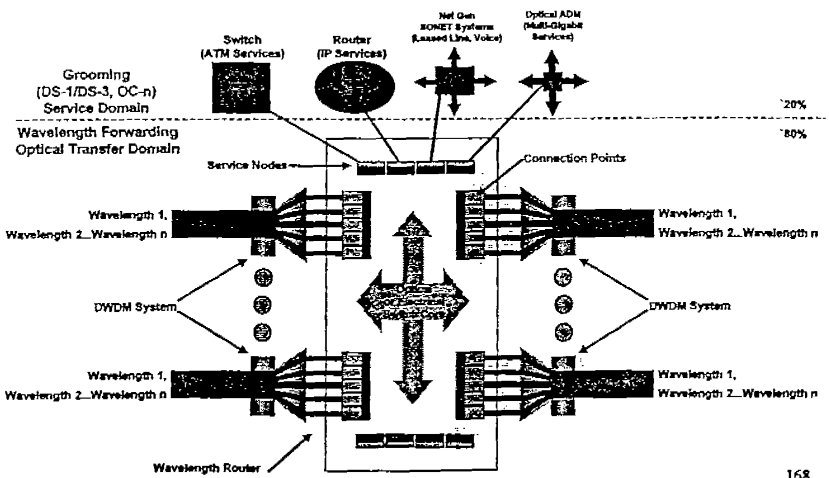
Optical Switch/Router



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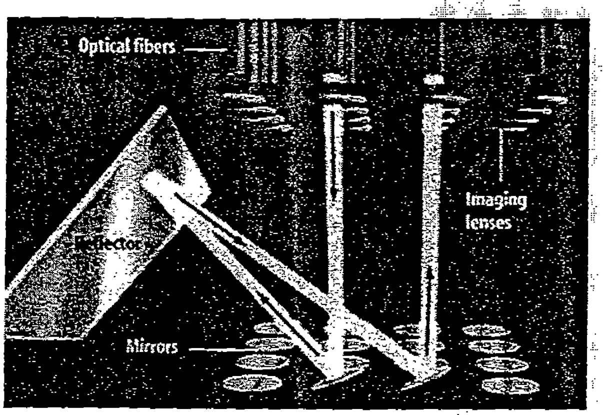
All Optical Switching

- There are several methods for photonic switching
  - MEMS
    - micro-electro-mechanical systems use arrays of microscopic mirrors to reflect light from input port to output port
  - LCD
    - liquid crystal display uses liquid to bend the light
  - Ink-jet printer/fluidics
    - use heat to create bubbles in fluid channels that then reflect and direct light

Evolving Optical Switches

- Enable optical mesh networks with a granularity of OC-48 (2.5 Gbps)
- Lucent LambdaRouter
  - lightwaves are switched using micro-mirrors
    - same principle as when shining a flashlight at a hand-held mirror - changing the position of the mirror changes the direction of the beam's reflection
  - 256 ports, each starting at 40 Gbps - a total capacity near 10 Terabits per second
  - Can intelligently switch/route wavelengths without any opto-electronic conversions
    - the lightwaves tell the mirror what bend to make to route the light appropriately using a digital wrapper (optical equivalent of packet header)

Lucent MEMS Switch



Source: MIT Technology Review

Evolving Optical Switches

- Optical Micro-Machines
  - MEMS based switches (MicroElectronic Mechanical Systems)
  - array of thousands of microscopic mirrors to direct light
  - fabricated on silicon chips - low cost VLSI CMOS foundry processes
  - OMM claims its MEMS based switches are 10x smaller, 10x faster, require 1/100th the operating power, and are scalable, allowing a 32x32 switch matrix to be fabricated on a single chip
- Xros (now Nortel) is also focusing on the micro mirror technology
  - can scale to 1152 wavelengths

Evolving Optical Switches

- Agilent Technologies
  - Using ink jet printer technology to switch packets in optical cross-connects
    - Tiny enclosures filled with gas sit behind the ink in jet printers. In front of each enclosure is a minute nozzle. When a character is called for, the gas behind the nozzles that form the letters is heated, and the ink is shot onto the paper.
    - Agilent is embedding tiny liquid-filled cavities in the switch fabric. If the packet is to stay on the same network, the liquid remains cool and the packet passes through unscathed. If a switch is required, the liquid is heated and turns to gas. By using gas with the correct reflective properties and precisely positioning the cavity, the light is bounced in the right direction.

Intelligent Optical Networking

- Adding more wavelengths presents service providers with a new challenge: cost-effectively managing the increasing number of wavelengths to provide fast, reliable services to their end customers.
- Digital wrappers promise to provide network management functions such as optical-layer performance monitoring, error correction and ring-protection capabilities on a per-wavelength basis.
  - Standardized as part of submarine cabling systems, and both the ITU and the new Optical Internetworking Forum have accepted the standard for landline fiber systems.
  - Lucent has unveiled its proprietary version of the standard, developed by Bell Labs, called WaveWrapper

Intelligent Optical Networking

- Lucent WaveWrapper places a small digital "wrapper" around each input wavelength.
  - These wrappers carry information such as restoration signals, what type of traffic the wavelength is carrying and where it is headed
  - As the wavelength moves around the network, the nodes read the header. It scans for originating and terminating details, information about whether it's an IP or ATM signal and commands such as strong forward error correction.
  - Systems then can determine the health of the signal, whether it needs to be rerouted and if the necessary equipment exists to receive the signal at its intended destination.
  - Submitted as a standard to ANSI T1 - Telecommunications Standards Committee, the Optical Internetworking Forum (OIF), and the International Telecommunication Union (ITU).

Intelligent Optical Networking

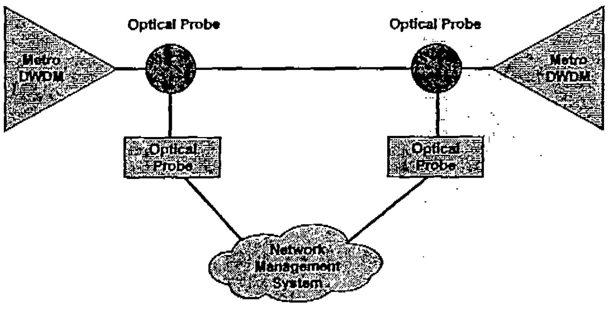
- The challenge is to deal with each wavelength individually.
  - It is necessary to understand what is happening on each wavelength in order to route and rearrange a wavelength across different carriers' networks.
  - To understand the wavelength's personality, it must be monitored.
  - This capability takes intelligence.

Optical Network Management

- Optical network operators will require new tools, including
  - Optical channel analyzers
  - Power balancing techniques
  - Tunable filters
  - Physical restoration techniques
  - Control plane signaling

LIDO 177

Optical Probe Monitoring



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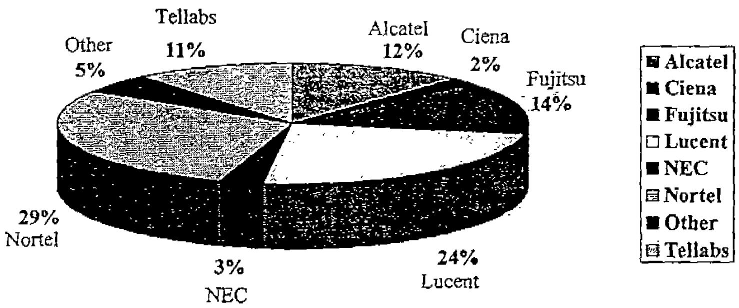
Optical Market

- Global spending on optical equipment is expected to soar to US$ 44 billion this year, up from US$ 31 billion in 1999. (RHK Inc).
- The US market for optical equipment in 1999 reached US$ 12.3 billion.
- RHK further forecasts the market will reach US$ 89 billion in 2003.
  - The market for optical components alone could surge to US$ 27 billion by 2003.
- Other forecasts suggest telecom carriers will spend up to US$ 1 trillion on next-generation gear in under 20 years. (McQuillan Consutling)

Optical Market Share
US$12.3 Billion in 1999



Source: Ryan, Hankin and Kent
WDM & Optical Networks: Market Share

Optical Networking Vendors

- Agilent Technologies, Alcatel, Alidian, Astral Point, Avanex, Cambrian (now Nortel), Cerent (now Cisco), Chiaro Networks, Chorum Technologies, Chromatis Networks (now Lucent), Ciena, CoreTek, Corvis, CyOptics, Cyras Systems, Ericsson, E-Tek Dynamics, Equipe, Fujitsu, Geyser, Giga A/S (Denmark), Gotham, JDS Uniphase, Lightera (now Ciena), Lightwave Microsystems, Lucent, Lynx Photonic, Monterey Networks (now Cisco), NEC, New Focus Inc., Nortel Networks, Novalux Inc., ONI Systems, Optical MicroMachines, Optical Networks, Osicom Technologies, Pirelli (now Cisco), Qtera (now Nortel), Quantum Bridge Communications, Siara Systems (now Redback), Sirocco (now sycamore), Sycamore Networks, Tellabs, Tellium, Tenor Networks, Wavesplitter, Xros (now Nortel)

附件三

LIDO Telecommunications Essentials™
Broadband Access Alternatives

Lili Goleniewski
The LIDO Organization, Inc.
www.lidoorg.com
lili@lidoorg.com
415-457-1800

Telecom WebCentral
www.telecomwebcentral.com

The Growth of Broadband Access

- Communications Industry Researchers (CIR) claim that approximately 1.6 million users signed up for broadband Internet access (1.5Mbps or higher) in 1999. They predict this will grow to 31.7 million users by 2003.
- The main drivers are believed to be
  - consumers' desire to find information valuable to them and to "be connected"
  - consumers' desire to experience the multimedia spectacle of the Web

The Growth of Broadband Access

- eMarketer reports indicate cable modem broadband access has taken an early lead over DSL adoption, but DSL will overtake cable modem access by 2003, with a projected 10.95 million subscribers. The two together will constitute approximately two-thirds of all broadband deployment.
- eMarketer reports there were 3.49 million business users of broadband in 1999, and this figure is projected to reach 11.3 million within 3 years as SMEs exploit cheaper broadband access methods like DSL and wireless broadband.

Global Broadband Access Trends

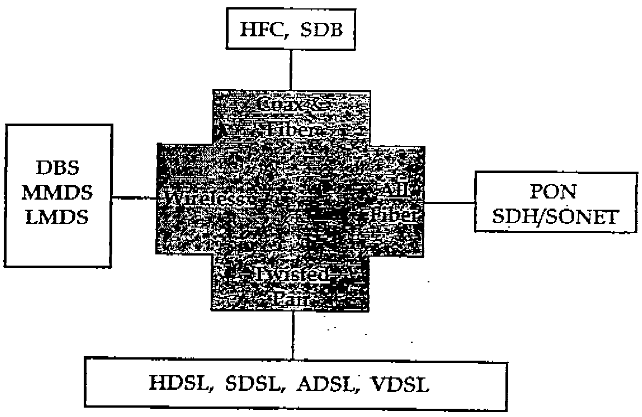
- Demand for broadband services in Europe and Asia will surpass the US by 2010.
- According to COMSYS the global broadband market will be worth US$ 580 billion by 2010. They predict that households and SMEs, rather than the traditional corporate customers, will account for most of the market.
- Increased economic growth and greater dependence on high-speed networks will lead to higher demand in Europe than the US by 2005 and in Asia by 2010. There will be 100 million addressable SMEs globally by that time but only 14 percent of those will be US-based.

Global Broadband Access Trends

- The number of broadband subscribers in the Asia-Pacific region is forecast to surge from 452,900 at year-end 1999 to 11.3 million by the end of 2003, according to the Yankee Group.
- Cable modem and ASDL will be the most popular forms of access, taking 46 percent and 42 percent of the market respectively by year-end 2003.
- Broadband providers across the region are all focusing on SMEs and home offices as a way into the mass market.

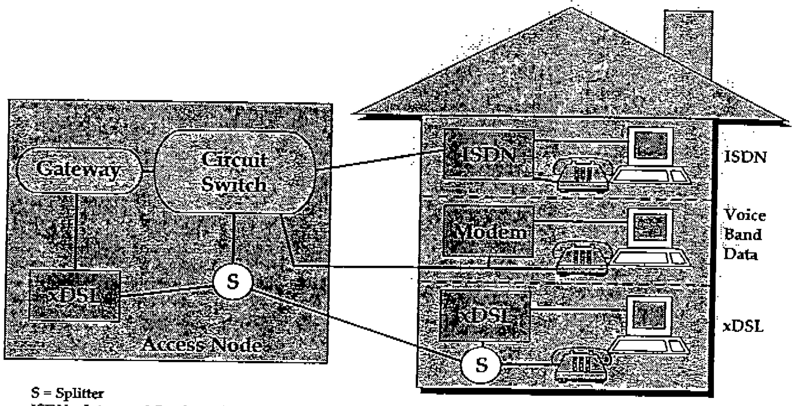
LIDO 5

Broadband Access Alternatives



LIDO 6

Twisted Pair Access

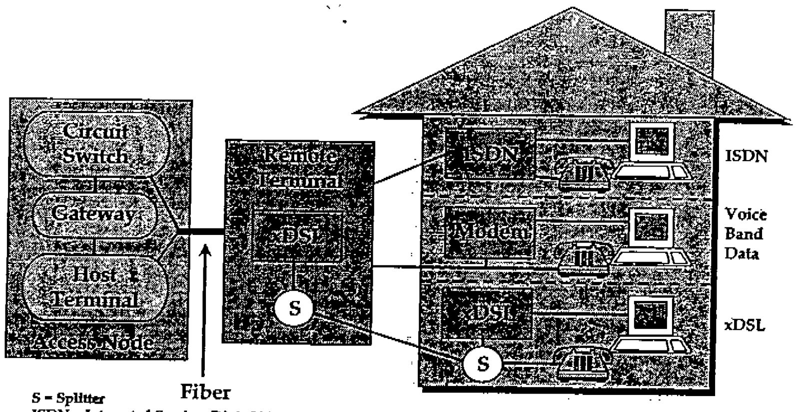


S = Splitter
ISDN = Integrated Services Digital Network

LIDO

Adapted From: Lucent Technologies

Remote Twisted Pair Access



S = Splitter
ISDN = Integrated Services Digital Network

LIDO

Adapted From: Lucent Technologies

xDSL Technologies

- DSL (digital subscriber line) emerged from Bellcore (now Telcordia) as a technique to filter out the incessant background noise or interference on copper wires and allow clearer connections through the use of electronic intelligence (in the form of DSL modems), at either end of a phone line.
- DSL modems are limited in transmission distance, generally ranging up to 18,000 ft./5.5km
  - new specs are increasing the permitted distances
- DSLs are point-to-point connections.

LIDO 9

Basic Elements of xDSLs

- High bandwidth transmission
- Efficient modulation or line coding techniques
  - defines now many bits are carried in a single cycle (Hz)
- Echo cancellation
  - allows full duplex transmission on a single electrical path
- Frequency splitting
  - used in ADSL and RADSL to derive separate voice and data channels
- Retain telephone power in event of power failure

LIDO 10

Factors Affecting xDSL

- Attenuation
  - Signal loss, or attenuation is a function of frequency. As frequency increases, the distance the signal can travel decreases by the square root of the frequency.
  - Higher frequencies lose power more rapidly, limiting loop lengths
- Resistance
  - As signals are transmitted through wires at very high frequencies, a phenomenon called the skin effect occurs. As electricity migrates to the skin, resistance increases because less of the wire is used. This increased resistance weakens signals.
  - Skin effect is why there are no services above 1 GHz over wired media.

Factors Affecting xDSL

- Crosstalk
  - When two adjacent wires carry signals, the possibility exists that signals from one wire will enter the other wire as a result of electromagnetic radiation.
  - Crosstalk increases with increasing frequency, a principal cause of signal degradation at the frequencies required by high-speed services.
  - Affects how many pairs within a cable can be used to deliver DSL service
- Phase Error
  - Higher frequencies are also a little slower, which causes a phase error - introduces bit errors where modulation techniques depend on phase

Factors Affecting xDSL

- Loads & Taps
  - loaded pairs cannot be used for DSL, bridge taps can cause distortions
- Loop Carrier
  - xDSLs must work with or around loop carrier systems
  - only HDSL and IDSL can work with existing DLCs
- Other external impairments
  - leakage, impulse noise, narrowband interference,
- Overall Quality
  - the general quality of the copper pair greatly affects the performance of xDSLs

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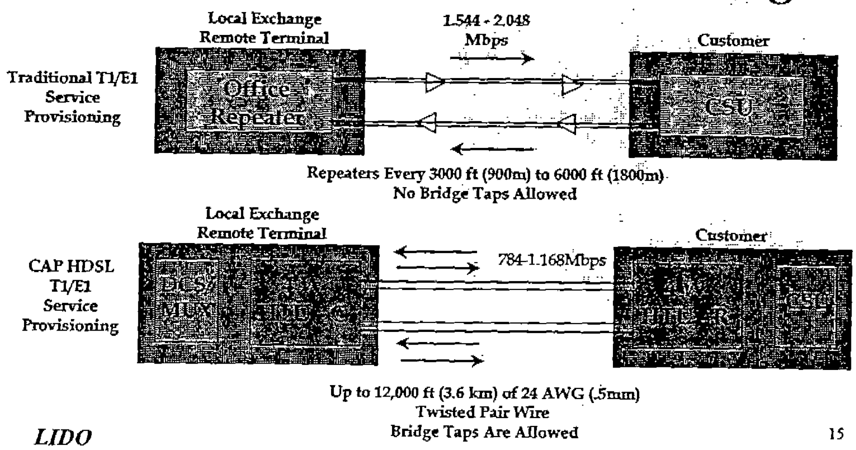
HDSL (High Bit Rate Digital Subscriber Line)

- Symmetrical, full-duplex service of 784 Kbps/1.168Mbps
  - aggregate bandwidth equal to T-1 (1.544 Mbps) or E-1 (2.048 Mbps)
- Two (T-1) or three (E-1) twisted copper pairs
  - up to 12,000 ft /3.7 km on 24 AWG
  - up to 9,000 ft/2.7 km on 26 AWG
- Requires no repeaters, loop conditioning or pair selection
- Carrierless Amplitude and Phase Modulation (CAP) modulation technique
- ITU G.991.1 and ANSI T1E1.4 Tech report 28

LIDO 14

HDSL versus Traditional T1/E1 Provisioning



HDSL (High Bit Rate Digital Subscriber Line)

- Allows faster and lower-cost provisioning of digital service
- Good solution for increasing the number of access lines via DLC transport
- Applications include replacement of local repeatered T1/E1 trunk, local frame relay alternative, PBX interconnection, traffic aggregation

HDSL2 (High Bit Rate Digital Subscriber Line)

- HDSL2 spec expected to be ratified by ANSI soon
- Single twisted copper pair over distances up to 12,000 ft / 3.6 km
- Symmetrical full duplex service up to 768 Kbps
- Will probably use CAP (carrierless amplitude modulation) line encoding
- Until the spec is ratified, products are proprietary
  - ADC Telecommunications, PairGain Technologies, ADdtran
- 392,000 subscribers by 2002 estimated by the Yankee Group.

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IDSL (ISDN Digital Subscriber Line)

- ISDN without the telephone switch, a DSLAM (DSL access multiplexer) shunts traffic to a data network
- Symmetrical, full duplex, always on service
- Offers 128 Kbps in each direction, unlike ISDN, it cannot be channelized
- Uses same transmission technology as BRI ISDN - 2B1Q line coding
- Twisted pair up to 18,000 ft/ 5.5 km

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SDSL (Symmetric Digital Subscriber Line)

- Also referred to as single-line DSL
- Single twisted copper pair up to 18,000ft/5.5km
- Symmetrical full duplex service
- Multiple data rates up to T-1 and E-1
- SDSL services are available, at speeds below T-1
- Applications include replacement of local repeatered T1/E1 trunk, fractional T1/E1, PBX interconnection, multirate ISDN, Switched 384 Kbps, local frame relay alternative, traffic aggregation, high speed residential service
- ITU G.shdsl (working title) and ANSI T1E1.4 HDSL2

MSDSL (Multirate Symmetrical Digital Subscriber Line)

- A descendant of SDSL
- Single twisted copper pair up to 18,000ft/5.5km
- Symmetrical full duplex service
- Eight variable line rates (operating distance)
- Aggregate bandwidth ranging from n x 64 Kbps up to 2 Mbps
- Autorate plug-and-play configuration

ADSL (Asymmetrical Digital Subscriber Line)

- Principle driver is Internet access
- ADSL-1 standard: 1.5/2 Mbps downstream, 16- 64 kbps bidirectional
  - 1.5-2 Mbps, 24 AWG, .5mm, 18,000 ft/5.5 km
  - 1.5-2 Mbps, 26 AWG, .4mm, 15,000 ft/4.6 km
- ADSL-2 standard : 6/8 Mbps downstream, up to 640/800 kbps bidirectional
  - 6.1 Mbps, 24 AWG, .5mm, 12,000 ft/3.7 km
  - 6.1 Mbps, 26 AWG, .4mm, 9,000 ft/2.7 km
- ITU G.992.1 and ANSI T1.413 Issue 2

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ADSL (Asymmetrical Digital Subscriber Line)

- Allows for simultaneous voice and Internet traffic on the same phone line
- Reserves the bottom 4 KHz of spectrum for voice traffic
- Filters, known as splitters, are used at each end of the copper pair to split the frequency bands, the lower frequencies are sent to the local exchange, the high frequencies are sent to the ADSL modems

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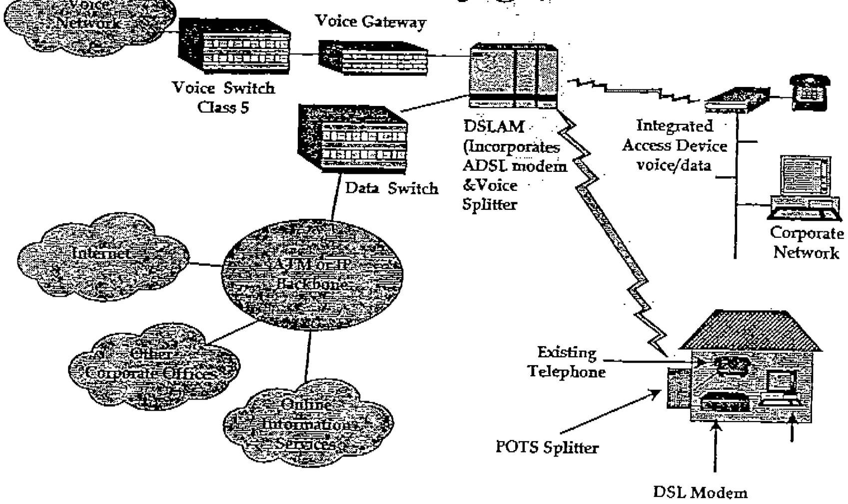
ADSL (Asymmetrical Digital Subscriber Line)

- DMT vs CAP - interoperability problems
- CAP (Carrierless Amplitude and Phase Modulation)
  - uses Quadrature Amplitude Modulation (QAM)
  - adapters less expensive
  - more susceptible to interference

ADSL (Asymmetrical Digital Subscriber Line)

- Discrete Multitone Technology (DMT)
  - standardized by ANSI (T1.413, Issue 2), ETSI and the ITU (G.dmt, now G.922.1)
  - DMT spectrum divided into 256 4KHz carriers
  - variable number of bits put on each carrier
  - prototype tests show
    - faster
    - less prone to interference
    - carries data over longer distances
    - more costly

ADSL Configuration



LIDO 25

DSL Access Multiplexers (DSLAMs)

- Designed to concentrate hundreds of xDSL access lines onto ATM or IP trunks and then route them to the ISP
- DSLAMs aggregate dedicated DSL pipes up to routers or multiservice edge switches
- Combine ADSL bit coding and ATM cell switching
- Allow ATM demarcation point to be at the local exchange or at the customer premise

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Voice over DSL

- Emerging as the "killer app", particularly for small business
  - According to Cahners In-Stat Group voice-over-DSL services will generate US$1 billion in revenue in the next year - and this is just for voice and related services such as messaging, call forwarding, and conferencing
  - using a single DSL connection, service providers will be able to deliver high-speed data access and up to 16 telephone lines
  - businesses with 20 to 49 employees are the best target group
  - customer needs an Integrated Access Device (IAD) - combines data and voice traffic onto a single DSL line
    - Vendors include Alcatel, CopperCom, Copper Mountain Networks, Efficient Networks, FlowPoint (now Efficient Networks), Jetstream Communications, Lucent, Motorola, Nortel Networks, PairGain, Tollbridge Technologies

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ADSL

- ◆ Applications include Internet access, remote LAN access, voice over DSL, DSL bonding.
- ◆ Equipment providers include
  - ◆ 3Com, Alcatel, Cisco, CopperCom, Copper Mountain, Diamond Lane, Efficient Networks, Ericsson, Intel, Jetstream Communications, Lucent, Microsoft, Netopia, Nortel, Orckit Communications, OpenCon Systems, Paradyne, Promatory, Rockwell, Texas Instruments, Toll Bridge Technologies, Turnstone Systems, Westell Technologies
- ◆ Service providers include
  - ◆ Ameritech, Belgacom, Bell Atlantic, BellSouth, BT, Concentric, Covad, Deutsche Telekom, Flashcom, France Telecom, Frontier, GTE, HKT, Jato, Level 3, MCI WorldCom, New Edge Networks, NorthPoint, PSINet, Qwest, Rhythms, SBC, Singapore Telecom, Sprint, Telecom Italia, Telecom NZ, Telenor A/S, Telia AB, Telstra, Uunet, US West, Verio

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ADSL Lite

- Universal ADSL Working Group (UAWG) was established to develop a lower speed, lower cost consumer version of ADSL, also referred to as splitterless DSL.
  - The founding members of UAWG included Alcatel, Ameritech, Analog Devices, Aware, Bell Atlantic, Bell South, British Telecom, Compaq Computer, Deutsche Telekom, France Telecom, GTE, Intel, Lucent, Microsoft, NTT, Rockwell, SBC, Singapore Tel, Sprint, Texas Instruments and U.S. West.
  - The device became known as G.Lite (G.922.2), or also referred to as splitterless DSL

LIDO 29

ADSL Lite Characteristics

- Downstream rates of up to 1.5 Mbps and up 512 Kbps upstream. Distance up to 24,000 ft / 7.2 km
- No "truck roll" required (estimated at US$200 per dispatch) to install splitters
  - installation of microfilters may still require a service call
- Use microfilters between the wall jacks and the phones to equalize impedance.
  - As current flows through a wire, a resisting force, called impedance, slows it down. In a stable circuit, impedance stays constant and can be dealt with easily. However, since home telephone systems are dynamic, phones continually go on- and off-hook, the impedance is constantly change. Shifting impedance disrupts data, which, in the absence of a splitter, is on the same wire as the phone traffic.

LIDO 30

ADSL Lite Characteristics

- Reduced powering and computer processing needs
  - Some G.Lite modems borrow a portion of their processing power from the host PC's CPU. The aim of this approach is to reducing modem costs.
- Since G.Lite operates at lower rates, the chip sets use less power
  - makes it easier to add these modems into other types of equipment and into local exchange racks
  - G.Lite equipment an achieve densities four to eight times greater than full-rate ADSL.
  - Could become a big issue in achieving high penetration rates in the residential market
- Rallied the industry around a standard line coding scheme - G.DMT

G.Heavy

- Full-rate spliterless systems are becoming available, minimizing the advantages of G.Lite
  - Support 8 Mbps downstream and up to 1 Mbps upstreams.
    - Platforms are in available or in development from Alcatel, 3Com, 3Wire, Orckit Communications and Westell Technologies.
    - Systems are being tested or deployed by Belgacom, BellSouth, SBC Communications, Bell Atlantic and Telecom Italia (as of 11/99)

ADSL - Europe

- Sweden's Telia AB
  - announced plans for near-nationwide availability
  - aggressive G.lite rollout plans
- TeleDanmark A/S
  - also aggressive G.lite rollout plans
- Deutsche Telekom AG
  - signaled their intention to offer DSL on a nationwide basis
- Telekom Austria
  - awarded a contract for 20,000 ADSL lines to Alcatel
- The Benelux countries are also rolling out ADSL

LIDO 33

ADSL Europe

- European DSL and cable modem service rollouts are estimated to be 12-18 months behind similar efforts in the US
- The ADSL Forum reported about 70,000 DSL lines to be installed in Europe by year's end 1999
- Sharp competition between cable modem and DSL providers is expected in Belgium, the Netherlands, Norway, Sweden, Finland and France (Telecom '99 Daily Oct.15)

LIDO 34

RADSL (Rate Adaptive Digital Subscriber Line)

- Adapts data rates dynamically, based on changes in line conditions.
- Can operate over a wider range of loop lengths and conditions, up to 18,000 ft
- Can operate with symmetrical or asymmetrical send/receive channels
- Downstream rates from 600 Kbps to 7 Mbps, upstream from 128 Kbps to 1 Mbps
- Most RADSL devices use DMT encoding

VDSL (Very High Bit Rate Digital Subscriber Line)

- Single twisted copper pair
- 13-52 Mbps downstream, 1.5-2.3 Mbps upstream
- Loop length range is very short
  - operating distance from 1000-5000ft / 300-1500m
- Performance degrades over longer distances
- Applications include high-definition TV and multimedia Internet access
- ITU G.vdsl (working title)

VDSL (Very High Bit Rate Digital Subscriber Line)

- ◆ Being developed by Aware, Inc
- ◆ Standards efforts underway in ANSI, ADSL Forum, ATM Forum and DAVIC
- ◆ Four technologies proposed, including CAP, DMT, DWMT, and SLC
- ◆ Goal is less power dissipation and lower cost than ADSL

LIDO 37

DSL Market

- According to Broadband Intelligence, there were 700,000 DSL users worldwide by the end of 1999. They predict that by 2008, among those users with PC connections, some 14 million will use DSL.
- According to Alcatel, more than 2 million users, many of them in the U.S., bought DSL in 1999.
- Renaissance Worldwide reports that 2.5 percent of households worldwide were using DSL to access broadband service at year end 1999. They predict it will rise to 9 percent by 2004.

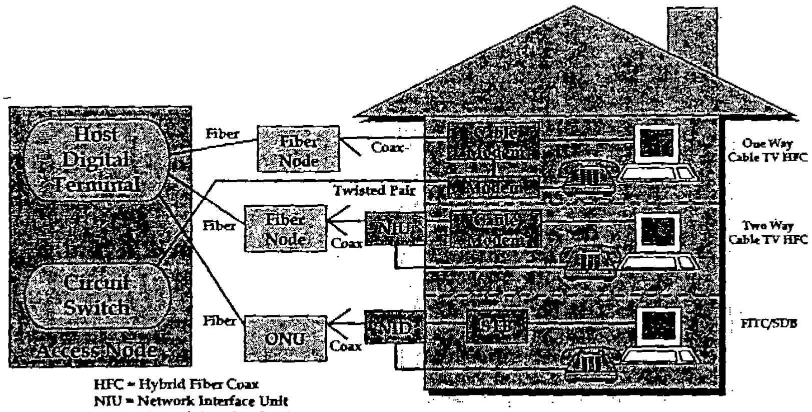
LIDO 38

DSL Market

- IDC predicts that by 2003 the total number of DSL households in the US will grow from the current 330,000 to 9.3 million.
- Jupiter Communications expects 5.7 million DSL users by 2003.
- Dataquest predicts that in 2003 vendors will ship 12.4 million DSL ports, compared to only 937,000 ports in the first half of 1999.
- Communications Industry Researchers report that the xDSL product and services market was US$252 million in 1999, and predicts it will grow to US$10.4 billion by 2003.

LIDO 39

Hybrid Fiber/Coax



HFC = Hybrid Fiber Coax
NIU = Network Interface Unit
NID = Network Interface Device
SDB = Switched Digital Broadband

Adapted From: Lucent Technologies

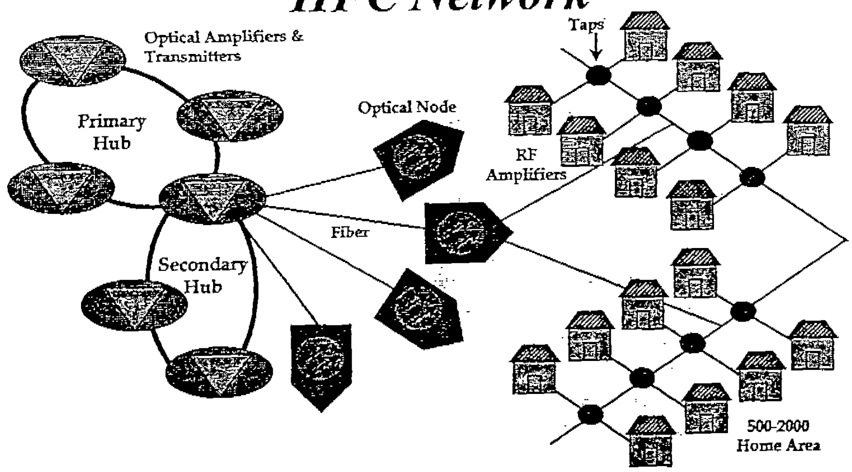
LIDO

HFC (Hybrid Fiber Coax)

- Supports telephony, broadcast video, and interactive broadband services
- Fiber in the backbone and access network
- Fiber termination point supports 200-2000 homes, with 200-500 being the norm
- Coax to the home, 750 MHz, two-way subsplit system
- $200-600 per customer to upgrade one-way system to two-way. Start ups may have to invest two to three times as much. (IEEE Spectrum 5/99)

LIDO 41

HFC Network



LIDO 42

HFC (Hybrid Fiber Coax)

- Bus topology, shared access coax bus
- Uses a passband modulation scheme
- Multiple access coax system represents a hostile environment
  - requires additional signal processing to overcome impairments.
- Requires a cable modem for data communications services
- AT&T feels that it can easily support 420 customers with a single 6 MHz TV channel

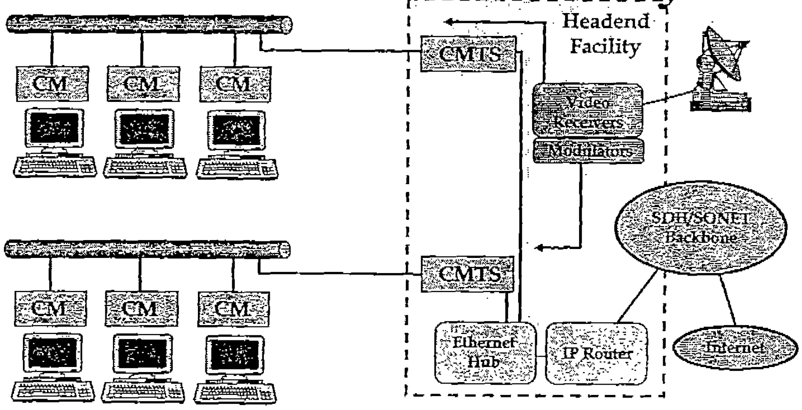
LIDO 43

Cable Modems

- Allow high-speed data access via Cable TV infrastructures
- Function like a special purpose routers linking the cable network's layer three to another network or device
- Generally an external box with cable and Ethernet connections
- Key cable modem manufacturers include
  - 3Com, Arris Interactive, Askey Computer, Cabletron Systems, Cisco Systems, Com21 Inc., General Instrument, LANcity Corp., Motorola, Philips Electronics, RCA, Samsung Information Systems of America, Sony, Terayon Communications Systems, Thomson Consumer Electronics, Toshiba America Information Systems, Zenith Network System

LIDO 44

Cable Modems
LAN Oriented Connectivity



CM = Cable Modems
CMTS = Cable Modem Termination System

LIDO 45

Cable Modems Characteristics

- Downstream data rates up to 36 Mbps
  - 42-750 MHz range
  - 64/256 QAM modulation technique
  - more bits per second
- Upstream data rates up to 10 Mbps
  - 5-40 MHz range
  - QPSK and 16 QAM modulation technique
  - better noise-resistance

LIDO 46

Cable Modem Standards

- CableLabs Multimedia Cable Network Systems (MCNS)
  - Data Over Cable System Interface Specification (DOCSIS)
  - PacketCable
  - OpenCable
- DAVIC Digital Video Broadcasting (DVB)
  - European Cable Communications Association (ECCA) EuroModem specification
- IEEE 802.14

CableLabs

- DOCSIS (Data Over Cable System Interface Specification)
  - also called CableLabs Certified Cable Modems
  - 64/256 QAM downstream, up to 36 Mbps, QPSK upstream at 2.56 Mbps
  - Ethernet connection to PC, TCP/IP encapsulated in Ethernet frames between cable modem and headend
  - Baseline privacy specification - relies on the use of both the 40- and 56-bit versions of the DES encryption standard
  - Recognized by the ITU - specifications will be formalized under J112.X, where X will denote the region.
  - Over 20 vendors have announced plans for DOCSIS
    - in Europe includes Cable & Wireless PLC, Cocom, NTL Group Ltd. and StjarnTV

CableLabs

- DOCSIS compliant companies (as of Sept. 1999)
  - 3Com
  - Arris Interactive
  - Askey Computer
  - Cisco Systems
  - General Instrument
  - Philips Electronics
  - Samsung Information Systems of America
  - Sony
  - Terayon Communications Systems
  - Thomson Consumer Electronics
  - Toshiba America Information Systems
- CableLabs has also certified Cisco's cable modem termination system (CMTS) for DOCSIS compliance
  - CMTS also provided by Motorola, not currently DOCSIS compliant

LIDO 49

CableLabs

- Focused on data and in its latest version also voice
- Does not support European cable standards
  - 8MHz channels, 65MHz frequency range for upstream signals, and compliance with Europe's broadcast downstream standard
  - led to development of EuroDOCSIS which combines North American DOCSIS standard with those elements of the DVB/DAVIC specification needed for DICSIS to work in Europe
- DOCSIS has a major headstart over EuroModem
- PacketCable 1.0 specification deals with transmitting multifeatured IP phone calls over HFC.
  - Allows four independent IP voice channels through a single cable modem

LIDO 50

CableLabs

- CableLabs OpenCable is a program to publish specifications that will define digital cable network interfaces, as well as the nature of next-generation cable set-top boxes.
- MCNS will be joined in Open Cable set-top boxes with advanced digital video compression circuitry to create terminals capable of supporting next-generation video and the entire gamut of current and coming Internet and Web-based applications

IEEE 802.14

- Cable TV Media Access Control (MAC) and Physical (PHY) Protocol
  - 64/256 QAM modulation downstream
  - QPSK and 16QAM modulation upstream
  - ATM specified as media access control
    - from headend to cable modem

DAVIC/DVB

- Digital Audio-Video Interoperability Committee (DAVIC) / Digital Video Broadcasting (DVB)
  - ECCA EuroModem specification
  - Addresses video, audio, data and voice services
    - enables a single multiservice platform, using ATM as the transport protocol
  - ITU-T J.38 Annex A
    - 64/256 QAM modulation downstream, QPSK modulation upstream
  - Some think may eventually take as much as 70% of the total European cable modem market
  - Interoperability between EuroModem and EuroDOCSIS may render the argument moot

LIDO 53

EuroModem Consortium

- TeleDanmark Kabel TV (Danmark)
- Helsinki Media (Finland)
- France Telecom (France)
- Deutsche Telekom (Germany)
- o.tel.o (Germany)
- Cablelink Ltd. (Ireland)
- Casema (Netherlands)
- CasTel (Netherlands)
- Telenor Avidi (Norway)
- StjarnTV-Natet AB (Sweden)
- Telia InfoMedia TeleVision AB (Sweden)
- Cablecom Holding AG (Switzerland)
- Palet Kabelcom (Netherlands)

LIDO 54

VoIP over HFC

- Thanks to deregulation and advancements in Class 5 replacement switches and IP telephony, the environment is ripe for cable providers to become CLECs or long distance carriers.
- Currently 90% of cable telephony is supported over circuit-switched networks. This will continue to be the case until 2001-2202.
- IP telephony over cable, specifically hybrid fiber coax (HFC) networks, is predicted to grow over the coming years.
  - Strategis forecasts that 12% of US households will have cable-based IP telephony by the end of 2005.

VoIP over HFC

- Circuit-switched telephony services are already offered
  - AT&T, Cablevision, Comcast, Cox Communications, MediaOne Group
- Operators will be able to offer either VoIP or circuit-switched service elusively, or in mixed packages.
- VoIP over cable is in early stages of development

VoIP over HFC

- Research efforts being led by PacketCable working group, part of the CableLabs organization.
  - DOCSIS 1.0 cable modem standard
  - DOCSIS 1.1 addresses real-time applications like telephony. Adds measures like dynamic QoS.
- Key issues include
  - voice quality in terms of latency, fidelity, jitter, packet loss, and reliability at the customer end
  - legacy signaling support, data security and theft of service security, scale, and feature deployment at the service provider end
  - also provider-specific issues like implementing systems for PSTN gateways and gatekeepers, provisioning, billing, and network maintenance.

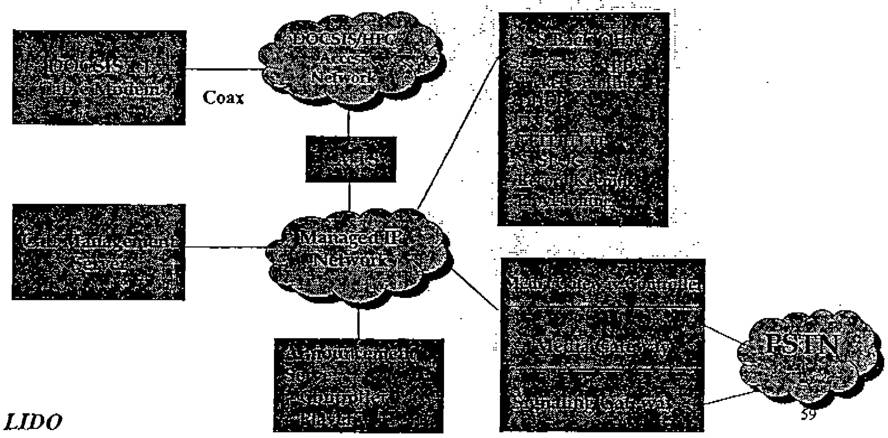
LIDO 57

VoIP over HFC

- Implementation of DOCSIS standards will be vital. The second version deals with enabling timing-sensitive voice and multimedia packets to share an HFC network with timing-insensitive pure data packets.
  - DOCSIS 1.1 enables the mode to recognize a non-data packet and switch to it instantaneously from whatever data packet it is working on.
  - Requires CMTS/router at the edge of the cable access network and by the cable modem.
    - Edge CMTS/router needs the intelligence to isolate traffic flows and apply policy-based QoS treatments in real time. Traffic flows need to be isolated by service provider, application, and subscriber so that during times of congestion, flows within their SLAs are maintained and flows exceeding their SLAs are discarded first.
    - Operators than map the DOCSIS-based flows to IP specs like DiffServ and MPLS to manage the handoff to the core IP network.

LIDO 58

Cable-based IP Telephony



VoIP over HFC

- Challenges operators face include
  - how will operators provide detailed, sophisticated, end-to-end service-level agreements
  - how will operators adjust to the need to do maintenance, which will become more critical
  - how will operators evolve from a broadband video provider to a mission-critical service provider

Cable Market

- According to Broadband Intelligence there were an estimated 1.6 million cable modem users by the end of 1999. They predict that by 2008, among those users with PC connections, 33 million will use cable modems for broadband access.
- According to Strategis Group, worldwide cable modem shipments for 1999 exceeded 2.2 million
- Renaissance Worldwide reports that 4 percent of households worldwide were using cable in 1999. They predict it will reach 12.6 percent by 2004.
- Paul Kagan & Associates estimates that the number of cable modem users could grow to 14.5 million within the next five years.

LIDO 61

Cable Modem Market

- By the year 2002, Forrester Research predicts that cable modems will be in 80% of the projected 16 million "broadband connected" homes in the US
- IDC predicts that by 2003 there will be 9 million cable-modem homes in the U.S.
- Jupiter Communications predicts 7.7 million cable-modem homes in the U.S. by 2003
- Yankee Group predicts 7 million broadband homes by the year 2003, with cable modems having a 61% market share, compared with DSL's 39%.
- Communications Industry Researchers report the market for cable modems in 1999 was US$860 million, and predicts it will grow to US $8.6billion by 2003.

LIDO 62

Cable Modem Market

- Cable modem deployment in Europe is just beginning
  - installed units number in the hundreds, not hundreds of thousands
- Most operators are focusing on consumer markets
- It currently costs the operator about US$450 per connection for equipment installation
  - Ovum predicts the costs to drop to US$200 by 2001

HFC and Cable Modems

- Major concerns include security, privacy, reliability and return path issues.
- Subdividing nodes alleviates bandwidth constraints and reduces ingress noise
- Service providers include include @Home Network, 21st Century Communications, Ameritech, AT&T Broadband & Internet Services (formerly TCI), BellSouth, Cablevision Systems, Capital Cable, Charter Communications, Coast Cablevision, Comcast, Cox Communications, Cable,Deutsche Telecom, GTE, MediaOne Group, SBC, SNET, Time Warner, US West

FTTC (Fiber to the Curb) / SDV (Switched Digital Video)

- Driven by interactive multimedia
- Fiber to the curb
  - OC3 (155 Mbps) bidirectionally, from local exchange to host digital terminal (HDT)
  - HDT to Optical Network Unit (ONU) - downstream rates up to 52 Mbps, upstream up to 20 Mbps
  - Optical Network Unit (ONU) supports 4-60 homes
- Twisted copper pair (s) to household
  - short distance - 1000ft/300 meters

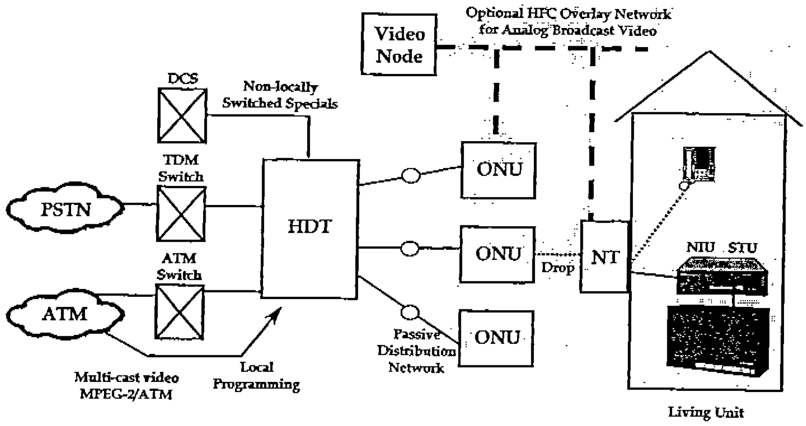
LIDO 65

FTTC (Fiber to the Curb)/ SDV (Switched Digital Video)

- Optional 550 MHz coax underlay
  - for ONU (optical network unit) power and analog signals
- Switched star topology
- Dedicated point-to-point connections
- Modulation approach
  - baseband signaling in which time division multiplexed signals are digitally transported
- ATM-based switching

LIDO 66

FTTC/SDV Configuration



FTTC (Fiber to the Curb)/ SDV (Switched Digital Video)

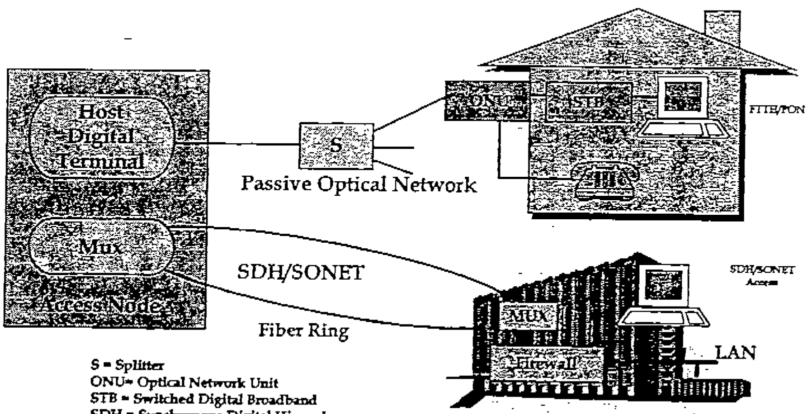
- CAT-16 short-distance modulation (developed by Bellcore) standardized by ITU and DAVIC
- Up to 1400 channels possible
- Requires that all media streams are digitized
- Requires video servers at the system head end
- Requires digital set-top box at subscriber end
- Higher cost than HFC from node to home

FTTC (Fiber to the Curb)/ SDV (Switched Digital Video)

- Easily upgraded to interactive broadband full-service networks
- Allows carriers to offer a multitude of new revenue-generating services over a single integrated platform
- Best solution for interactive broadband services
- Supported by Bell Atlantic, Nynex, BellSouth, SBC Communications, NTT, AT&T Network Systems, Broadband Technologies, General Instruments, Scientific-Atlanta, British Telecom, US West

LIDO 69

Fiber Access



S = Splitter
ONU= Optical Network Unit
STB = Switched Digital Broadband
SDH = Synchronous Digital Hierarchy

Adapted From: Lucent Technologies

LIDO

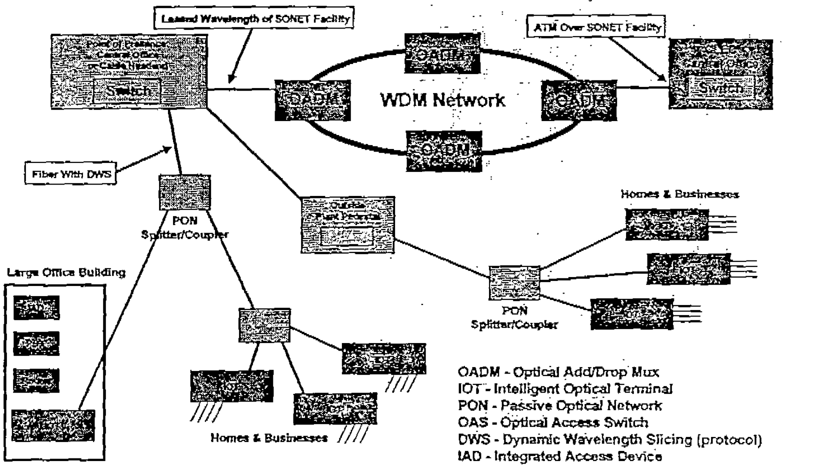
FTTH (Fiber to the Home) / PON (Passive Optical Network)

- From 155 Mbps in both directions
- Fiber from service node to the optical splitter
- From splitter, multiple fibers fan out to terminate on a single-home ONU
- Point-to-point architecture
- Secure transmissions

FTTH (Fiber to the Home) / PON (Passive Optical Network)

- Broadband service applications
- Robust outside plant, low maintenance cost
- Target wireline solution
- Cost still too high, capital cost per subscriber reported to be around US$3000
  - predicted to be US$1700 or less by 2001
- Alcatel, BT, France Telecom, NTT, Optical Solutions, Siemens, the RACE BAF project

Passive Optical Network

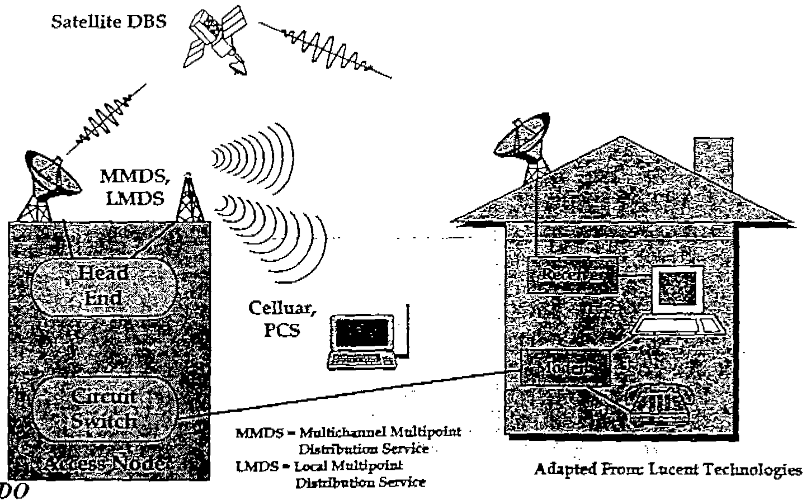


OADM - Optical Add/Drop Mux
IOT - Intelligent Optical Terminal
PON - Passive Optical Network
OAS - Optical Access Switch
DWS - Dynamic Wavelength Slicing (protocol)
IAD - Integrated Access Device

LIDO 73

Source: Quantum Bridge

Wireless Access



MMDS = Multichannel Multipoint Distribution Service
LMDS = Local Multipoint Distribution Service

Adapted From: Lucent Technologies

LIDO

Wireless Access

- Fixed wireless is a strong contender to fill the gap where existing wiring is not up to the job, or there is no wiring at all.
- The cost of a radio link has been halving every seven years, while its data capacity has been doubling every three years. (Teligent, IEEE Spectrum 9/99)
  - With those two trends in combination, the cost-to-capacity ratio in wireless communications has been dropping by 50 percent every 2.1 years.
- For wireless links, construction and equipment costs have a ratio of roughly 20:80, whereas for a terrestrial optical-fiber link the ratio would be 90:10 (WinStar, IEEE Spectrum, 9/99)

Wireless Access

- Estimates are that about one in five people in the US lives in roughly one in five people in the US lives in areas too remote for any fast wireline access to the Internet.
- Also, it is estimated there are some three million small-office workers in modest industrial parks without fast access.
  - According to Adaptive Broadband Corp, out of 2.1 million small offices in non-core business districts, only 30% are able to receive a DSL.
  - Fiber penetration to commercial building and multiple dwelling units is projected to be at best some 3 percent (HeliOss Communications)

Wireless Access

- Wireless systems often operate in a point-to-multipoint mode - the antenna communicates with several different clients' antennas usually installed within a well-defined region.
- Since the air is a shared medium, like cable, the maximum transmission rate that can be provided to any one client decreases as more clients are served.
  - Clients who need the greatest bit-rate obtainable from a system (like an ISP for example) may find it advisable to arrange for a point-to-point system.

LIDO 77

Direct Broadcast Satellite

- VSAT technology, provides over 150 digital channels
  - Set-top includes MPEG-2 decoder
- Ku-band systems one-way, new Ka-band systems will support two-way
- Approximately 20 million subscribers worldwide, but predominantly for television
  - Watching two different channels on different TVs requires two receivers
- Jupiter predicts that by 2002 some 2% of consumers with Internet access will be using satellite connections
- Players in two-way systems include AOL via US$1.5 billion stake in Hughes Electronics (two way service planned for 2002), Hughes Network Systems, iSky (planned for 2001), Globalstart, Microsoft with Gilat Satellite Networks.

LIDO 78

l *Multipoint*

Distribution Service (MMDS)

- Operates in the 2-3 GHz band
- 30 mile/50 km range
- Terrestrial line-of-sight microwave
- Suffers from environmental interference
- Digital television system
  - can support over 150 digital channels
  - Set-top includes MPEG-2 decoder

Multichannel Multipoint Distribution Service (MMDS)

- First licensed in the 1970s, when they were called Multipoint Distribution Services (MDS), to broadcast 6 MHz television channels.
- In 1996, the FCC expanded the band to cover its present range and allowed for multichannel services called MMDS.
  - Licensees of these channels could compete directly with cable TV providers (for this reason MMDS is sometimes referred to as wireless cable)
- In 1998 the FCC permitted MMDS providers to offer interactive two-way services for the Internet
  - requires upgrading to bidirectional systems

Multichannel Multipoint Distribution Service (MMDS)

- According to the Wireless Communications Association International there are some 5 million MMDS customers in 90 nations, but this is mostly for TV service.
  - One million of these customers receive services from 250 providers in the US alone.
  - More than three million subscribers to the service in Budapest, many with access to the Internet
- MCI Worldcom, Sprint and PacBell bought rights to offer MMDS.
- Equipment still expensive
  - US$1000 to $2000 for installing a two-way radio
  - Providers include Clarity Wireless (now Cisco), Proxim Inc., Spike Technologies, Wavetrace Inc., Wireless Inc.

LIDO 81

Local Multipoint Distribution Service (LMDS)

- ◆ Terrestrial line-of-sight microwave
- ◆ Operates in 1.3GHz in the 28-45 GHz range
- ◆ Typical installation has a central base station with an ominidirectional antenna serving many residences, each of which has directional dish aimed at the base station.
- ◆ Operations over microcells of 1-5 km, serving 5,000-10,000 homes. Systems works best if users are within 3.5 km of base station.

LIDO 82

Local Multipoint Distribution Service (LMDS)

- Digital LMDS supports two-way, symmetrical, switched broadband networking
- Average mix can support 156 video channels and up to 7,000 DS0 main lines
- Downstream from 51.84-155.52 Mbps, return link of 1.544 Mbps
- Also referred to as Multipoint Video Distribution Service (MVDS) and Broadband Wireless Access (BWA) in Europe and Local Multipoint ~~Distribution~~ Communications Service ~~(LMDS)~~ LMCS in Canada.
- Market for LMDS is expected to exceed US$ 2 billion by 2003. (IEEE Spectrum 9/99).

Local Multipoint Distribution Service (LMDS)

- Allows competitive local exchange carriers (CLECs) to offer broadband services to the small- and medium- sized business market more cost-effectively than competitors banking on more established fiber networks.
- Service providers include
  - Advanced Radio Telecom Corp., AT&T's Teleport Communications Group (TCG), BizTel (a TCG company), Infranet Svenska AB, Speedus.com, Teligent, Touch America, Winstar Communications, WNP Communications (acquired by Next Link)
- Equipment manufacturers include
  - Bosch Telecom (bought TI LMDS division), Ericsson, HeliOss Communications, Lucent (bought HP's broadband unit), Newbridge Networks (with Millitech agreement), Northern Telecom (bought Broadband Networks), P-Comm North America

Wireless Access

- Industry analysts indicate that over 50 million wireless local loops were deployed globally by the end of 1999.
- Other predictions indicate that by the year 2003, over half the new fixed phone lines installed worldwide each year will be wireless.
- Focus Communications estimated the broadband wireless access market in the US to be US $1 billion in 1999. They further expect the LMDS market to reach more than US$16 billion by 2005.

Source: IEEE Spectrum 9/99

LIDO 85

Drivers for Telco Strategies

- Slower rates of growth or even decline in their core business of providing fixed-link telephone services
- Competition from alternative networks
- Ongoing demand growth for non-voice services

LIDO 86

Decision Factors

- Status of embedded distribution plant
- Service strategy of the network operator
- Cost of installing a new distribution system
- Performance level of the distribution system that is required to implement the services strategy

Services Strategy

- Legacy services
  - telephony
  - special services (ISDN, data services, etc.)
- New services
  - IP services
  - interactive broadband services
    - Internet access
    - remote access/telecommuting
    - SOHO
    - teleshopping
  - broadcast & interactive video

Multi-Tier Wan Architecture

- Most broadband network services are planned as separate overlay networks
- Incremental deployment via edge switches
  - separate networks for separate services
- The key to cost saving is in the integrated access

LIDO 89

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