An Overview of GPON in the Access Network

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Agenda

- Access Networks – the last mile
  - Definition
  - Trends
- PONs
  - Revenue split history and projections
  - Characteristics of a PON
  - Terminology and Architecture
  - PONs and FTTx
  - PON Implementations
    - APON and BPON
    - GPON
- Market Forces at Work
- Entrisphere an Ericsson Company
  - Quick Facts
  - Products

Definition of an Access Network

- Series of wires, cables, and equipment lying between a consumer/business telephone termination point and the local telephone exchange
  - Telephone termination point = where a telephone connection reaches the customer
- Oldest and most important asset a telecom operator owns
- Constantly evolving:
  - Customer churn
  - New services are offered
  - Regulatory drivers
- Most complicated and costly part of an operator's infrastructure

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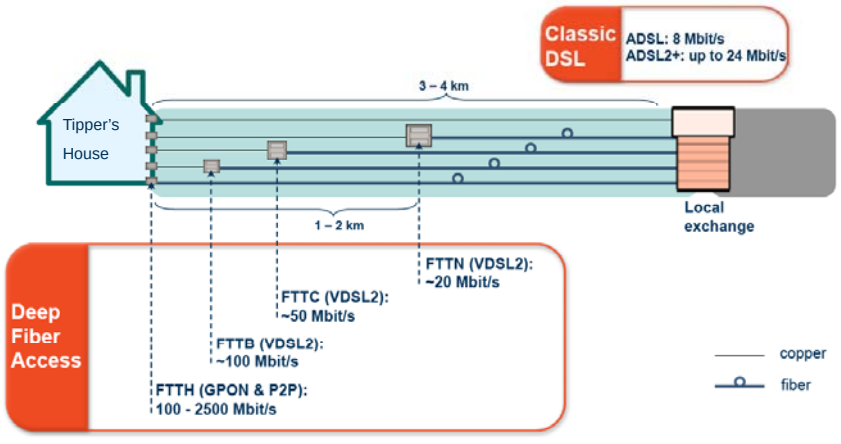
Elements of an Access Network



•We'll go into greater detail on FTTx later in the presentation ….

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Copper and Fiber Facts

North America

Table 17.3
Local Transmission Technology
(Bell Operating Companies)
Cable Sheath Kilometers

Year End	Total	Copper		Fiber		Other	
1991	4,163,640	3,955,622	95.0 %	196,791	4.7 %	11,228	0.3 %
1992	4,214,804	3,965,406	94.1	238,406	5.7	10,994	0.3
1993	4,264,569	3,976,100	93.2	280,017	6.6	8,450	0.2
1994	4,256,253	3,934,243	92.4	314,660	7.4	7,350	0.2
1995	4,319,068	3,960,343	91.7	351,907	8.1	6,819	0.2
1996	4,339,067	3,947,238	91.0	386,011	8.9	5,819	0.1
1997	4,396,205	3,974,204	90.4	416,105	9.5	5,896	0.1
1998	4,473,351	4,009,772	89.6	449,554	10.0	14,026	0.3
1999 [1]	4,608,808	4,103,657	89.0	491,478	10.7	13,672	0.3
2000 [2]	5,761,869	5,132,364	89.1	613,646	10.7	15,860	0.3
2001	5,848,516	5,166,537	88.3	665,805	11.4	16,174	0.3
2002	5,791,105	5,086,669	87.8	692,031	11.9	12,406	0.2
2003	5,851,790	5,118,314	87.5	720,877	12.3	12,600	0.2
2004	5,942,045	5,166,481	86.9	763,132	12.8	12,433	0.2
2005	5,990,163	5,166,382	86.2	811,896	13.6	11,884	0.2

Working Telecommunications Channels
(Thousands)

Year End	Total	Copper		Fiber		Radio	
1991	118,654	114,047	96.1	4,605	3.9	2.3	0.0
1992	120,848	114,009	94.8	6,238	5.2	1.0	0.0
1993	124,191	115,496	93.0	8,694	7.0	1.4	0.0
1994	130,192	118,437	91.0	11,755	9.0	0.3	0.0
1995	136,231	122,975	90.3	13,255	9.7	0.3	0.0
1996	142,824	125,595	87.9	17,228	12.1	1.0	0.0
1997	149,429	128,436	86.0	20,992	14.0	0.3	0.0
1998	172,916	134,629	77.9	38,286	22.1	0.3	0.0
1999 [1]	186,387	138,691	74.4	47,696	25.6	0.0	0.0
2000 [2]	218,928	157,840	72.1	61,086	27.9	2.0	0.0
2001	228,705	152,441	66.7	76,263	33.3	2.0	0.0
2002 [3]	169,157	137,228	81.1	31,927	18.9	1.0	0.0
2003	158,890	127,652	80.3	31,237	19.7	1.0	0.0
2004	148,255	117,320	79.1	30,935	20.9	0.1	0.0
2005	137,254	110,033	80.2	27,221	19.8	0.1	0.0

Source: FCC, Industry Analysis and Technology Division, 2007Yankee, 12/05

More Copper and Fiber Facts

North America

	2005	2006	2007	2008	2009	2010	2011	CAGR
North American data								
Consumer DSL Access Lines	21,592.5	27,121.2	32,170.9	35,954.4	38,733.4	40,305.3	41,644.2	*11.6%*
Consumer FTTP Connections	400.0	950.0	2,000.0	3,830.0	6,450.0	10,220.0	14,805.0	*82.6%*
Consumer Switched Access Lines	123,111	119,665	118,335	116,615	116,501	116,583	116,100	*-1.0%*
Percentage of copper connections (Consumer)	99.68%	99.21%	98.34%	96.82%	94.75%	91.94%	88.69%	
Enterprise Switched Access Lines	73,431	71,858	69,813	66,871	63,346	59,844	58,562	-3.7%

- Vast majority of services still being delivered over copper loops in North America
- In 2008, still over 95% copper on consumer connections
- Verizon reported just over 1 million fiber connections recently but has 40 million consumer access lines
- On the enterprise side, about 12% of all buildings in North America connected via fiber

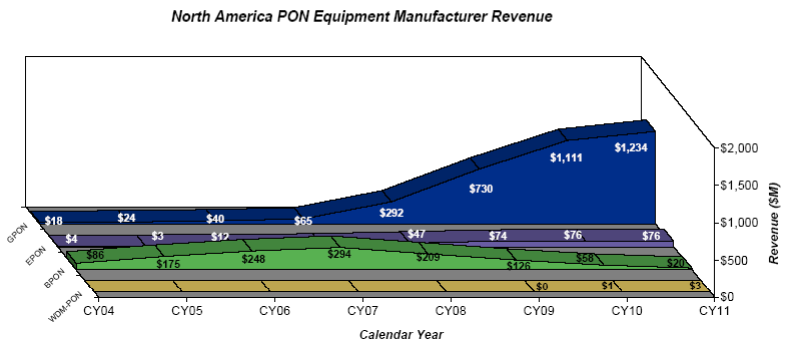
Source: FCC, Industry Analysis and Technology Division, 2007 Yankee, 12/05

Market Trends Summary

- Transport
  Theme: More bandwidth
  - More bandwidth for HDTV and IPTV – Triple Play
  - BPON being replaced by GPON
  - New builds all GPON
  - WDM PON enters the market in a few years
  - All IP/Ethernet access is gaining share (over ON)
- Cable Plant
  Theme: Slow but sure fiber build out
  - Services via copper are still predominant
  - Fiber replacement happening at rate of 1% annually

PON Equipment Revenue

North America



Source: Infonetics

Introduction – What is a PON?

- Passive Optical Network.
- Facilitates another (higher bandwidth) broadband access technology
- Competes with and complements xDSL, cable modem and fixed wireless
- With a PON, optical fiber is deployed either all the way or almost all the way to the end user (VDSL)
- Passive because
  - network only consists of passive light transmission components (fiber links, splitters and couplers)
  - This creates great cost savings for the provider (more reliable and less costly to operate/troubleshoot)
- PONs use a Point-to-Multi-Point (P2MP) topology

Introduction – What is a PON?

- Market Trends
  - PONs have been around for almost 20 years
  - Market adoption in NA and Asia has significantly increased in the last few years especially in Japan and the US.
  - Desire to provide “triple play” services is driving market growth. In the US, RBOCs are using PONs (think FIOS) to add TV programming so they can compete with the cable companies who are bundling voice and H.S. Internet to their standard video offering.
  - As per a recent Dell’Oro Group Report
    - Forecasted worldwide PON equipment revenues will reach almost $2 billion by 2011
    - 70% increase from last year
    - PON subscriber base is expected to increase five-fold over the next five years.

Some PON Terminology

- ODN – Optical Distribution Network
  - An ODN realizes the optical transmission from the OLT towards the users and vice versa. It utilizes passive optical components.
- OLT – Optical Line Termination
  - An OLT is the service provider endpoint of a PON and is placed in a CO or head end
- ONT – Optical Network Termination
  - An ONT is a device that terminates the PON and presents native service interfaces to the user. An ONT is typically located on the customer's premises.
- ONU – Optical Network Unit
  - An ONU is the PON-side half of the ONT, terminating the PON, and may present one or more converged interfaces, such as xDSL or Ethernet, toward the user. An ONU typically requires a separate subscriber unit to provide native user services such as telephony, Ethernet data, or video.

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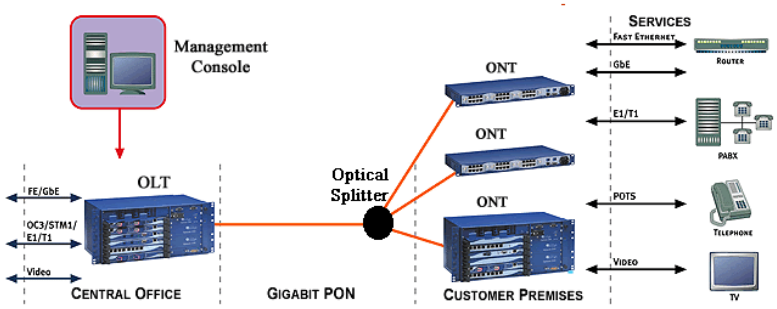
General Architecture



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How Do PONs Work?

- A PON uses a P2MP topology
- From the OLT a single strand of fiber goes out to a passive optical splitter/merger where its signal is split onto fibers terminating at up to 64 different ONUs or ONTs.
- Splitters can either be single stage (1 X 64) or cascaded (1 X 4 feeding into four 1 X 16)
- The transmit and receive directions operate on different wavelengths.
  - Upstream uses 1310nm
  - Downstream uses 1490nm
  - RF video overlay uses 1550 nm

How do PONs work?

- To transmit downstream
  - the OLT broadcasts all the traffic to every ONT on the PON through the action of the splitters.
  - Each ONT only reads the content of those packets that are addressed to it.
  - Encryption is used to prevent eavesdropping on downstream traffic.
- In the upstream direction
  - the OLT controls the transmissions from all the ONTs using an arbitration protocol.
  - Popular methods include a TDM timeslot arrangement, or a prescheduled packet-allocation or bandwidth-allocation scheme.
- "Ranging" is the difficult part
  - The OLT must coordinate the upstream transmission of all the ONU/ONT into proper timeslots
  - Physical delay from each ONT must be measured and figured into the "offset" along with the timeslot assignment so that upstream transmissions don't collide.
  - A misbehaving ONT can impact the entire upstream transmission
  - Aging of optical components can cause drift which requires constant monitoring by the OLT
- The operating speeds, frame formats, optical interface specifications, etc depend on the type of PON.

More on FTTx

- FTTx is the general term used to describe the penetration of optical fiber into the access network.
- FTTx can use P2P links to reach the end users or a PON based P2MP topology. Most current FTTx deployments use PON.
- The 'x' in FTTx stands for different things based on how close the fiber terminates to the end customer.
  - Fiber all the way to the Home or Business customer
    - FTTH or FTTB
  - Partial fiber to a point close to the customer and some other mechanism (usually copper pairs supporting xDSL) for the final link to the customer

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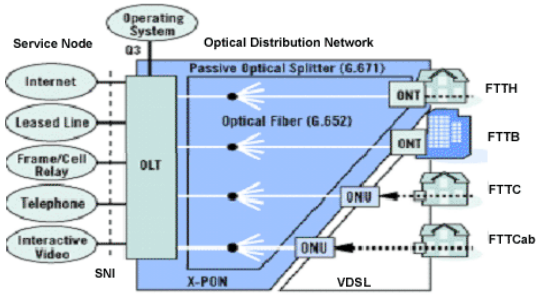
FTTx Explained

- FTTC – partial fiber to the Cabinet. Serves 8-24 customers.
- FTTC – partial fiber to the Curb
- FTTN – partial fiber to the Neighborhood. Both of these usually serve 400-600 homes.



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Types of PONs

- There are various types of PONs. The general technology is the same. The differences are in the specifications and upper layer protocols.
  - APON – ATM based PON uses ATM encapsulation of the transported data.
  - BPON – Broadband PON succeeded APON and also uses ATM encapsulation. Supports superior features, higher speeds and was standardized by the ITU-T.
  - EPON or GE-PON – Ethernet PON uses Ethernet for data encapsulation. Standardized by the IEEE in mid-2004.
  - GPON or Giga PON – Gigabit PON uses a new Generic Encapsulation Method (GEM) transport layer that supports ATM, Ethernet and TDM data transport.

Comparing PON Types

Characteristic	EPON (~2004)	GPON (~2003)	BPON (Late 1990's)
Speed – Down/Upstream in Mbits/s	1250 / 1250	2488.32 / 1244.16	622.08 (OC-12) / 155.52 (OC-3)
Native Protocol	Ethernet	GEM	ATM
Standards Body	IEEE	ITU-T	ITU-T
Downstream Security	Open	AES (counter mode)	Churingor AES
OA&M and management	Ethernet OAM, optional SNMP	PL OAM + OMCI	PL OAM + OMCI

PON Advantages

- Reduced OpEx – passive network implies easy upgrades, reduced CO wiring and space requirements and long plant life
- Reduced CapEx (vs. P2P architecture)
  - 16 to 128 customers per fiber
  - 1 (bi dir) fiber + (N+1) transceivers vs 2N fibers + 2N transceivers
- Increased revenue opportunities
  - Multi service: RF video, Data, voice, IP video (IPTV), E1/T1
- Scalable
  - New customers can be added easily and future bandwidth almost limitless with fiber

PON Standardization

- ITU-T, IEEE and FSAN are the main bodies involved in PON standardization.
- Full Service Access Network (FSAN) Group
  - Is an interest group for the world's leading telecommunications services providers, independent test labs, and equipment suppliers interested in promoting a common goal of standards for broadband fiber access networks.
  - The mission is to drive applicable standards, where they already exist, into the services and products in the industry
  - While simultaneously advancing its own specifications into the appropriate standard bodies to provide further definition to the Full Service Access Network.
  - FSAN has more than 50 members representing the leading implementers of Gigabit rate G-PON and B-PON Passive Optical Networking.
  - FSAN drove the initial APON standard.

PON Standardization

- ITU-T
  - Standardized BPON by way of the G.983.x family of standards
  - Standardized GPON by way of G.984.x
    - G.984.1 describes the service provider requirements for the system.
    - G.984.2 specifies the physical layer for all the data rate combinations in G-PON.
    - G.984.3 defines the transmission convergence layer
    - G.984.4 defines the OMCI on the system.
- IEEE standardized EPON in the 802.3 ah (EFM) standard in mid-2004

Operational Details – APON/BPON

- Based upon ATM as the bearer protocol
- Downstream transmission
  - Continuous ATM stream
  - Dedicated Physical Layer OAM (PLOAM) cells inserted into the data stream.
- Upstream transmission
  - Bursts of ATM cells
  - 3 byte physical overhead appended to each 53 byte cell in order to allow for burst transmission and reception.
- TX protocol based on a downstream frame of 56 ATM cells (53 bytes each) for the basic rate of 155 Mb/s, scaling up with bit rates providing for up to 224 cells in a frame for 622 Mb/s.
- The upstream frame format is 53 cells of 56 bytes each (53 bytes of ATM cell + 3 bytes OH) for the basic 155 Mb/s rate.

Operational Details – APON/BPON

- The downstream frame
  - Constructed from 2 PLOAM cells
  - One cell at the beginning of the frame and one in the middle
  - And 54 data ATM cells.
  - Each PLOAM cell contains grants for upstream transmission
  - As well as OAM&P messages.
- Upstream transmission consists of
  - Either a data cell, or
  - PLOAM cell

Operational Details – GPON

- Evolutionary technology based upon BPON
- GEM (GPON Encapsulation Method)
- Downstream transmission
  - 2.4Gbps
  - BW for one ONT is sufficient to supply multiple HDTV signals
  - QOS allows for delay sensitive traffic (voice)
- Upstream transmission
  - 1.24Gbps
  - Minimum BW can be guaranteed
  - Unused timeslots can be assigned to heavy users
  - QOS allows for delay sensitive traffic (voice)

Market Forces at Work

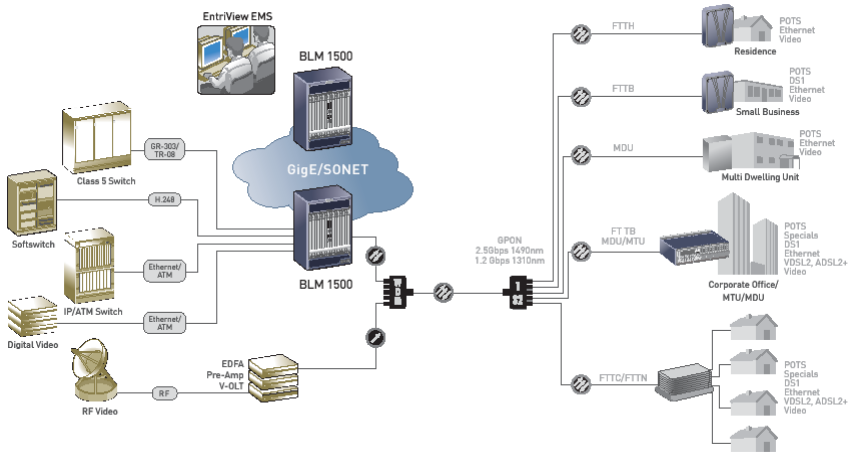
- What is the next killer app?
- My experience with HDTV
- Telcos need to compete with Cable Operators
- Landline Telco bread and butter is replaced by wireless
- Video content is the decision driver, POTS and Internet service tag along
- Triple play? Quad Play?
- Next gen Wireless Networks - LTE

Entrisphere – Quick Facts

- Founded in 2000
- Based in Santa Clara, Ca
- VC funding to get off the ground (Peter Bourne)
- BPON sales and GPON Trials in-process. ATT is the big one
- Announced acquisition by Ericsson on 2/12/07. Ericsson was a partner on a GPON bid in to AT&T prior to the acquisition
- Major announced GPON customer is AT&T. Several other trials underway
- Competitors – Tellabs, Alcatel-Lucent, Motorola, Fujitsu, Hitachi Telecom, Nokia Siemens, Calix

Entrisphere - Products

- BLM 1500
  - Multi-service access platform (functionally an OLT)
  - Provides POTS, IPTV, DSL, B-PON and GPON, Voice over Packet, Ethernet and other interfaces from a single chassis
  - Can serve 1344 POTS lines, 672 ADSL2+ and POTS combo lines, or 3,584 GPON ONTs.
  - Redundant non-blocking switch fabric
  - Has 2 variants – 80G and 320G capacities
  - Supports standalone, point-to-point, chain, ring and PON topologies
  - Supports both central office and outside plant (OSP) deployment
  - On the provider network side, can connect to a Class 5 switch, Softswitch or ATM/L2/L3 switch/router.



Entrisphere - Products

- T-series ONTs/ONUs
  - BLM T100 ONT
    - Located on the exterior of a home
    - 4 POTS, 1 data, 1 RF video port
    - Up to 100Mbps per home
  - BLM T151 ONT
    - SME ONT – supports legacy and next gen packet data services
    - 2 DS1, 4 POTS, 1 10/100 Ethernet, 1 video
  - BLM T300
    - MDU ONT – supports legacy and packet data services for up to 4 homes
    - 8 POTS, 4 10/100 Ethernet, 4 RF video ports

Entrisphere - Products

  - BLM T500
    - Large MDU/MTU ONU
    - 6 broadband slots (DS1, Ethernet, xDSL), 12 narrowband slots (POTS, ISDN)
    - Modular arch. – can add cards as required to increase capacity, services
    - Can be locally powered or line powered
- EntriView EMS
  - Northbound interfaces to legacy OSSs (using TL1) as well as next gen OSSs (using CORBA)
  - Provides Java based GUI that runs on any PC/workstation
  - Completed Telcordia's OSMINE certification
  - Can manage the BLM1500 as well as ONTs
- Outside Plant (OSP) Cabinets
  - Manufactured by CommScope and Emerson

Entrisphere - Products

- Models capable of housing 1,2 or 3 BLM1500s
- Compliant with GR-487-CORE

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