FEEDER FIBER INFRASTRUCTURE FOR THE SMALL TO MEDIUM BUSINESS DATA SERVICES

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Abstract

This paper investigates the business development and engineering advantages of utilizing ring topologies in last mile fiber-to-the-business applications. The use of traditional star or bus-star oriented network topologies become less than optimal when the realities associated with business services market dynamics and geographic circumstances are considered. It will be shown how the use of rings in the access network can reduce business development risks, is highly synergistic with existing fiber feeder plant, simplifies engineering and operations tasks over the life of the plant and can improve the MSO's service deployment velocity. All critical success factors for the MSO in the profitable deployment of fiber based business services.

INTRODUCTION

The access and transport fiber infrastructure upgrade investment made by MSO's in support of their residential broadband initiatives has positioned them well to become the major data services carriers in the growing 70B$ to 90B$ small to medium business data services market. ***In the U.S., MSO's collectively now have more access fiber passing small to medium businesses than any other competing communications entity.*** This paper assesses the advantages and potential problems associated with the use of fiber ring based access technologies which leverage fiber inventories to capitalize on this promising business development opportunity.

HFC feeder fiber is the key differentiating strategic element that is working in the favor of the cable service provider. For any carrier attempting to address the small business market space, the means for effective and efficient backhaul has been demonstrated to be one of the key barriers to market entry. Accordingly, MSO's must optimally leverage the use of existing dark fiber. Each fiber that passes pockets of businesses must be able to support as many subscribers as possible while providing meaningful service levels. Solutions must be able support multiple subscribers per feeder fiber (fiber-gain) while controlling risk, maintaining simplicity and providing low first-in cost.

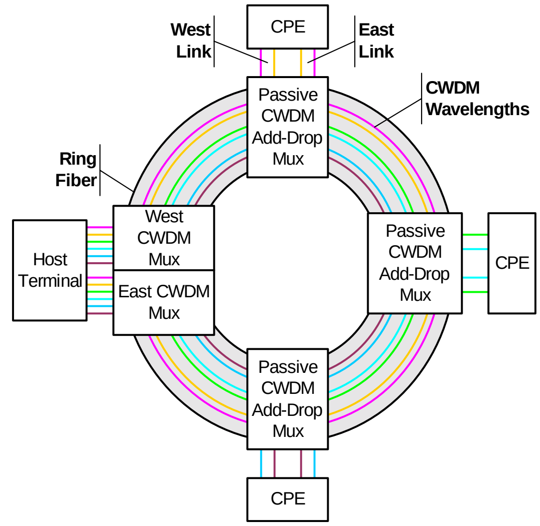
Many of the data oriented access solutions being circulated today are based upon classic bus or star local area network (LAN) topology principles that are implemented over either fiber or coax infrastructure. To achieve any degree of feeder fiber-gain these approaches generically require the use of either passive or active edge aggregation elements within a few thousand feet of the subscribers being served. Such architectures are quite suitable for applications where subscriber densities and service take rates are high and can be accurately predicted, e.g. urban or residential applications. Unfortunately for the MSO neither of these conditions typically exists when extending existing spare fiber for business building access.

There is a better way! This paper will explore the comparative strategic advantages of utilizing a fiber ring topology for accessing business buildings. Coupled with the emerging low cost ring based networking technologies such as Resilient Packet Ring[a] (RPR) and Multi-Protocol Label Switching (MPLS) Fast-Reroute[b] the MSO's can minimize deployment risks and while maintaining a high of degree of service flexibility. ***This paper will show how access fiber rings are highly adaptable to varied circumstances, reduce construction and operations demands and ease the impact on existing HFC feeder fiber.***

RING TECHNOLOGY OVERVIEW

Broadly, fiber ring technologies are based upon either optical add-drop (OAD) multiplexing or electronic add-drop (EAD) approaches. Each has its own advantages, however it will be shown that EAD approaches based upon emerging Ethernet technologies can greatly simplify deployment and operations demands while increasing the number of subscribers supported per ring.

Each station in a wave division multiplexed (WDM) OAD ring communicates to a host headend terminal over two pairs of dedicated optical wavelengths using a standard link aggregation protocol such as that found in Ethernet[c]. Each wavelength pair is routed in opposite directions around a diverse or collapsed path ring, as illustrated below.



WDM OAD Ring

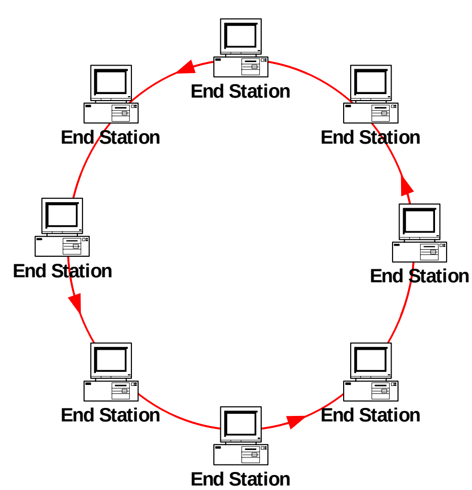
The number of stations which can be placed on an OAD ring is governed by a number of factors. For example, based upon the available wavelengths the maximum number of ring stations is one-half of the available wavelength count, e.g. a CWDM based ring can support a maximum of 9 stations per ring, assuming 2 wavelengths per station in each direction with a total of 18 wavelengths available. The combination of passive optical multiplexer and ring segment optical losses, e.g. water-peak attenuation, may also limit the number of ring stations based upon optical budget restrictions. The incremental insertion of new stations into a ring must be carefully planned to ensure that the optical performances of the new and existing ring stations are not adversely affected.

The OAD ring approach requires the MSO to accurately track to whom wavelengths have been allocated. If successful, hundreds or thousands of subscriber wavelengths, subscriber and headend-host switch ports and network service allocations will have to be accurately correlated and tracked on a regional basis over the life of the network. The problem is further complicated by the fact that network management automation tools do not typically extend to a manually provisioned optical layer. These challenges could become a serious liability threatening the MSO's ability to consistently provide a high degree of service reliability and integrity. The approach also presents a physical port scaling challenge at the host terminal, demanding two OAD multiplexers and optically interfaced switch ports per subscriber. ***A key advantage of the OAD approach is that the links between the host terminal and each CPE unit are dedicated and private; enabling the simple and effective physical layer security, privacy and individual station failure immunity associated with dedicated media connections while operating in a resilient shared media environment.***

The apparent ease by which the add-drop function is performed in an OAD solution leads one to anticipate a reduction in ring station and headend host switch complexity and expense. In a linear cascade of stations, used strictly for the purpose of providing best effort traffic over a single physical port, elegance in station design will indeed prevail since stations may be composed of simple physical layer fiber-to-twisted pair media converters. However the headend host switch must still bare the full brunt of being a carrier-class device. An additional complication arises from the fact that the headend host terminal(s) must economically scale on a per physical port basis for each port type required (e.g. 10baseT, 100bastT, 1000baseT, T1, T3 and etc.) as each subscriber is added, which can in turn drive up costs, headend space requirements and the need to track physical fiber or twisted pair port connections for each subscriber. Further, station complexity and cost increase dramatically with the inclusion of higher level functions such as support of OAD rings, multiple subscriber physical and logical ports, varied data types, managed services and QoS sensitive traffic; effectively becoming equivalent to the complexity and cost of a comparably featured EAD based ring station.

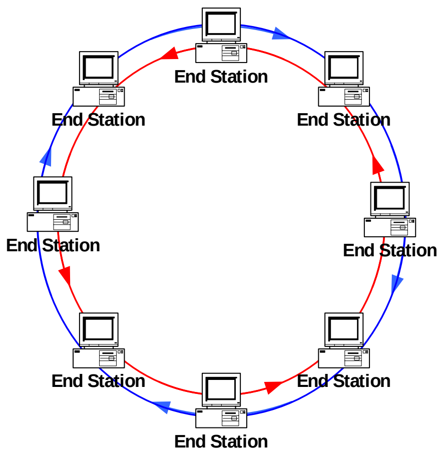
From a business development and management point of view these circumstances present a potential condition where OAD based solutions add unneeded equipment and operations expense. Over the life of the plant, headend and drop CWDM optical passives, headend host switch physical ports, headend O/E interfaces along with wavelength and switch port record keeping complications will greatly encumber the overall cost-performance of the solution. Fortunately, all of these costs can be minimized or eliminated through the alternative use of an EAD based approach.

All stations in an EAD based ring share a common set of fibers or wavelengths which greatly increases the number of stations a ring can support, for example RPR supports up to 255 stations per ring. Ring traffic is added to, dropped from or transits through each station in the ring. As previously mentioned, many of the data network architectures being derived for service provider applications, including rings, have roots in existing enterprise LAN technologies. The most common ring based LAN technology is Token Ring[d] (IEEE 802.5), which is based upon a single ring typically utilizing twisted pair copper media.



Single Ring Network

A more robust duel ring approach is used in Fiber Distributed Data Interface[e] (FDDI) and is implemented over either twisted pair copper or fiber media. The use of a dual ring gave FDDI a resiliency advantage not available in the simpler single ring approach.



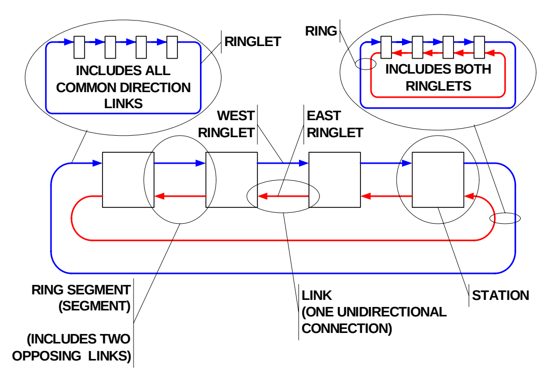
Dual Ring Network

In either case, Token Ring or FDDI, the use of rings within the enterprise has clearly not enjoyed the widespread success of star or bus-star technologies such as ATM and Ethernet. This has been principally due to higher costs and operational reliability issues associated with disruptions in ring continuity when workstations were inadvertently switched off, unplanned moves or interconnecting cabling failures[f]. However FDDI has been successful as a reliable high capacity link between core network elements such as servers and routers as well as between facilities in campus applications. In these cases the devices and interconnecting media are managed and stationary – thus they are far less vulnerable to inadvertent user manipulation.

Within the telecommunications domain, clearly the most widespread utilization of the ring topology is in the form of Synchronous Optical Network[g] (SONET). Like FDDI, SONET is based upon the principle of resiliency through the use of multiple rings, however by contrast SONET is not a data link layer technology and is incapable of performing packet switching functions on its own. SONET is the defacto standard for high reliability transport within the telecom industry, however its capabilities come at a price point that is sustainable for only the most demanding high revenue subscriber requirements. ***The reliability of SONET rings between fixed managed facilities has been extraordinary, virtually eliminating network outages due to fiber or equipment failures.***

EAD RING FUNCTIONALITY

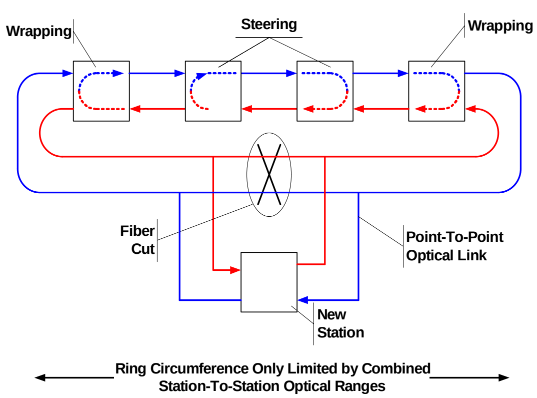
It will be useful to briefly review terminology and functionality associated with ring networks. The focus of this section will be on EAD rings while highlighting the key contrasts and similarities to OAD rings. A degree of commonality exists in the vocabulary used in the aforementioned ring standards, and for discussion purposes here the terminology adopted in the IEEE 802.17 RPR draft standard will suffice and is illustrated in the diagrams below.



Ring Terminology

The active elements on a ring are referred to as either stations or end-stations based upon the nature of the station's traffic. Stations that terminate all traffic are commonly referred to as end-stations. The term "station" will be used here since CPE or headend host devices rarely terminate all traffic. One station on the ring will serve as the ring's interface to the MSO's backbone network by aggregating non-local traffic into a few high-speed interfaces. Ring segments exist between stations and are composed of two opposing links. Most, though not all, access rings will be composed of two ringlets. Each ringlet-link is a half-duplex connection with directional signaling over an optical wavelength transported on a fiber or with the opposite ringlet-link in a single fiber WDM arrangement. Occasionally, due to circumstances associated with a lack of fiber, it may be desirable to operate the ring in an open single-ringlet mode where stations are simply daisy chained together, thereby forgoing many of the key carrier-oriented benefits of using ring-based equipment.

The counter rotating ringlets combined with a station's ability to reroute traffic in the event of a fiber cut facilitate the topology's well known resiliency protection capability. As illustrated below, stations can implement protection by either wrapping traffic at the stations adjacent to a ring element failure or by having all stations steer their traffic that was transiting the failure point away from the failure. Stations determine the condition of the ring by either continually circulating topology status information or by monitoring optical signal levels and are thus able to detect the failure and redirect traffic in less than 50ms.

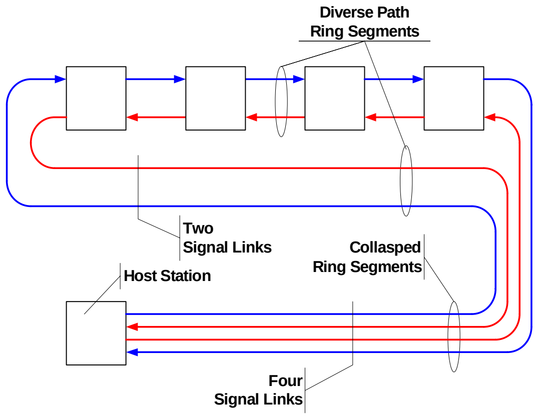


EAD Ring Protection

Typically fiber failures are accidental, but in the case where a new station is being added to an OAD or EAD ring a fiber cut is intentional and appropriate. Whether intentionally or accidentally cut the ring enters its protection mode preventing protected service failure to existing subscribers, for example a DS1 would not loose frame-lock. Once a new station is added to the ring all of the ring's stations automatically update their ring topology information and resume normal operation. It will be shown that the ability to insert a new station at any arbitrary location within a ring without interruption to protected services is a crucial benefit to using rings in last mile access applications.

A key attribute of an EAD ring is that each ringlet link is constrained to a simple point-to-point optical connection with no intervening passive devices. Each station regenerates the link for transmission to the next station allowing the link to operate over great distances with standards based optical devices. A signaling constraint is typically not placed on the length of a ring segment, and in turn the ring circumference is only limited by the combined lengths of each ring segment. In the last mile applications, station-to-station distances are typically less than 10km, virtually eliminating optical budget and dispersion constraints for both the initial ring deployment and future bandwidth enhancements. ***Decoupling the fiber plant from station optical budget constraints helps to both ease deployment concerns and insure that the plant will remain transparent to future upgrades.***

A fiber ring can be implemented around physically diverse path or within a single collapsed path as illustrated below. Two signaling links are required for each diverse path segment of an EAD ring, with each segment typically being supported by two fiber strands. Four signaling links are required for collapsed segments typically consuming four fiber strands.



Ring Segment Paths

As previously discussed, a segment's fiber strand usage can be reduced through the use of simple two wavelength WDM techniques utilizing optical combiners where existing fiber inventories are insufficient to support one link per fiber strand. Where WDM is used, each station's east and west optical interface's transmit wavelength must be appropriately coordinated, e.g. all west interfaces transmitting on 1310nm and all east interfaces transmitting on 1550nm.

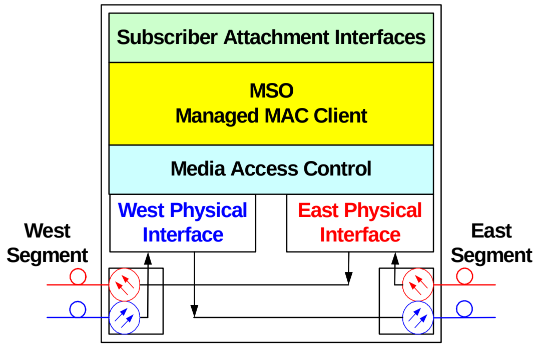
It is important to understand that a ring's segment's paths can diverge and merge multiple times along a common feeder fiber route and within one fiber feeder serving area. This attribute enables a great deal of planning flexibility while using existing fiber strand inventory still available within an HFC fiber feeder cable. ***Rather than focusing on the feeder's physical end points and spare fiber strands at each HFC node, a ring design proceeds by focusing on the feeder's many splice locations and a common set of spare fiber strands that are used in all of the feeder trunks and branches.***

ACCESS RING CHALLENGES

Though the use of ring topologies in access applications does address many of the difficulties encountered with alternative approaches, they can and will present challenges of their own. ***Under specific circumstances problems with regard to security, reliability and fiber utilization can arise in access rings.*** This section will point out these circumstances and explore methods that alleviate or eliminate their impact.

Since a ring is a shared media point-to-point topology, security, service theft and multi-point failures in either the ring fiber or stations must be accommodated. OAD ring applications must limit CPE access to those wavelengths specifically allocated. This is routinely achieved by placing the service drop's passive optical multiplexer in the outside plant (OSP) where it is secure and under the complete control of the MSO. Additionally, measures must also be taken to ensure that the ring's host headend aggregation switch provides suitable security measures to prevent successful substitution of a foreign station and/or the hacking of switch traffic or network control plane information. ***It is important to understand that, because OAD ring stations do not process neighboring station traffic, security and service theft issues are not eliminated, they are simply moved directly back to the ring's hosting switch.***

EAD ring technologies will pass a portion or all of a ring's traffic through each station on the ring. ***Mechanisms must be in place such that stations can be assured to be trusted entities; fortunately such mechanisms are native to the operation of EAD stations.*** An EAD station is typically composed of four functional layers as illustrated below.



EAD Station Function Block Diagram

The east and west physical layer interfaces provide optical linkages to neighboring ring stations. The media access control (MAC) entity manages add, drop and transit station traffic. The functional entity that is responsible for controlling all traffic presented to the subscriber attachment interfaces is the MAC client. The client is directly managed by the MSO's network management system. Traffic cannot be presented to subscriber interfaces until the client has been authenticated as a trusted network element and services have been setup by the management system; the station does not flood its switch ports to build its forwarding tables as found in a standard Ethernet environment. Station authentication and control processes are typically equipment-vendor specific, for example a system may restrict access to the network's control plane with an access control authentication technology such as RADIUS[h].

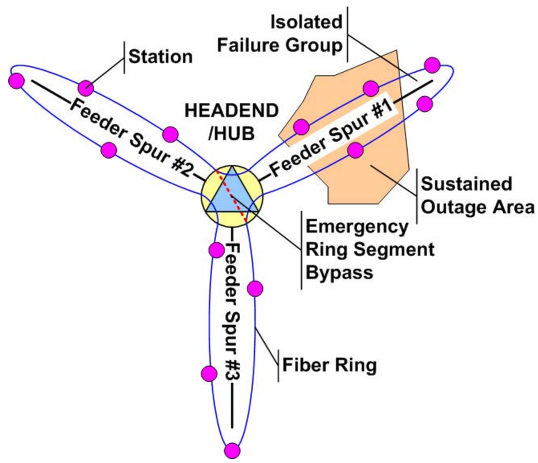
The conditions that can trigger service outages on a ring are dependent upon the networking technology used and the physical fiber path, collapsed or diverse. ***The behavior of fiber-cut induced service outage in collapsed path OAD or EAD ring is identical to that found in bus or bus-star topology; all stations downstream of a fiber cut experience an outage.*** Conversely a diverse path ring is typically resilient in the case of a fiber cut. However, multiple station failures can present a problem for EAD rings.

A multiple EAD station failure condition, though rare, may isolate or island subscriber traffic creating a service outage irrespective of how the ring fiber is deployed. The condition can be addressed simultaneously at both the local station and serving area levels. Multiple station outages can be caused by either a common widespread condition, such as sustained power outage, or a collection of simultaneous isolated station failures. To mitigate the possibility of multiple simultaneous isolated station failures in a carrier environment, experience has shown that each station should be a fixed-position managed device that is operated from a standby-power source. ***If a station standby-power source is not available, a local automatic optical bypass switch can be implemented at either the station or the building's service drop.*** Thus local station powering conditions are not likely to cause multi-station service outage conditions. A sustained utility power outage(s) within the ring's serving area that interrupts the operation of multiple stations is best addressed on a serving area basis.

Recovery from a sustained power outage may be possible through the use of optical bypass switches at each station. Historically in LAN environments this approach has not been successful due to the added cost and limitations in the number of sequential bypasses that can occur at once due to optical loss limitations. Given the relatively rare conditions under which multiple stations simultaneously fail, a strategic manual-bypass approach may be more appropriate.

Collapsed rings composed of fiber feeder segments can be equipped with sets of mechanical fiber strand splices at key feeder splice locations. Splice locations can then serve as a manual bypass point. In the event of a sustained local power outage, the effected sections of the ring can be bypassed at the nearest splice for the duration of the outage. Unfortunately, failed segments of diverse path rings cannot be so readily isolated, and measures must be taken at the hub/headend level.

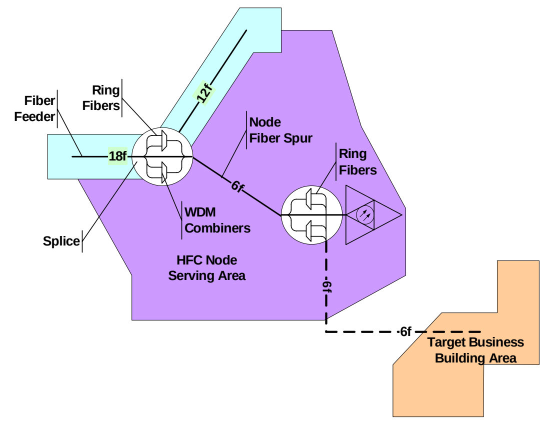
The business subscriber density within a headend or hub serving area is likely to result in a condition where a single EAD ring will route through a hub multiple times which facilitates an alternative bypass approach, as illustrated below.



Ring Spur Bypass

In this case an emergency manual or automatic optically-sensing bypass function is implemented at the hub for each ring-spur such that an effected spur is isolated for the duration of the outage. This restores the ring to full operation for the remaining subscribers on unaffected ring spurs.

When planning the deployment of collapsed fiber rings, circumstances will be encountered where the available spare fiber strands in a feeder cable will be insufficient to support a four fiber EAD ring segment. This condition is most likely to occur when attempting to extend ring fibers to a business location from a fiber feeder segment where fewer than four spare fibers are available. For example, a feeder spur to a lone HFC node typically contains 4 to 6 fiber strands with 1 to 2 strands held in reserve for advanced services; this is an insufficient amount of free fiber for the extension of a collapsed electronic add-drop ring using a conventional four fiber approach. In these cases ring fiber counts can be reduced by using either passive WDM or CWDM techniques, as illustrated below.



WDM Fiber Ring

In this case WDM combiners are implemented at the splice cases located at each end of the node's fiber spur. Implementing a WDM ring segment does impose additional optical requirements on the segment's stations. Each station's optical interfaces must transmit using different optical wavelengths and with sufficient power to overcome optical combiner insertion losses. For example, one station may transmit on 1310nm while the other may transmit on 1550nm. Other CWDM wavelengths may be selected as well. In any case, stations equipped with modular pluggable optical interfaces can easily accommodate this requirement while facilitating the use of higher power DFB transmitters for the support of ring segments up to 80km in length.

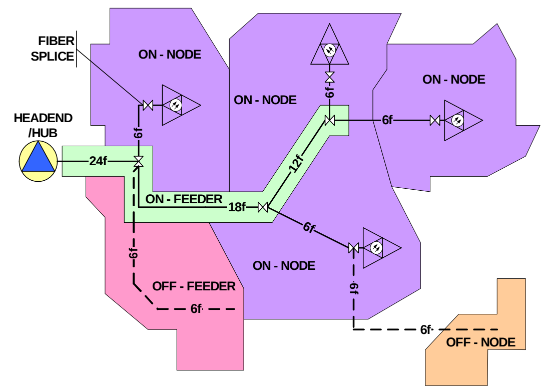
FIBER ACCESS CHALLENGES AND SOLUTIONS

Clearly the primary barrier to offering services via fiber is the cost to extend the fiber to the subscriber's building and subsequently to the subscriber's demark point. Fortunately in the majority of cases some portion of the MSO's fiber plant is within a few thousand feet of the building, however just being close usually is not sufficient. ***Effective strategies for both the targeted marketing of communications services and fiber build-out can greatly reduce risks and enhance business development success.***

Until recently the implementation of a fiber-based business service by an MSO has been based upon an incremental opportunity brought to the MSO by a service broker or by the subscriber directly. Historically, the service is typically implemented quickly and easily using a point-to-point approach. One or more feeder fiber strands are dedicated to the service at each of the subscriber attachment points to the MSO's backbone network. Unfortunately, due to limitations in available spare fiber media, this approach is not sustainable or scalable within a general business services deployment program. Alternatives which allow businesses to securely share common strands of fiber media are essential and available in both ring and non-ring topologies. ***The key attribute of a successful topology lies in its ability to flexibly adapt the diverse array of circumstances that are driven by market, geographical and operational circumstances.***

Physically, the business service market areas where the MSO is likely to enjoy the most success and velocity are those that are near existing fiber inventory and are typically underserved by legacy business service providers. Commonly these areas are suburban in nature with a relatively low density of business buildings and potential subscribers per street mile. Densities of 10 to 15 buildings and 15 to 20 businesses per street mile can be expected. This fact coupled with a low fiber service take rate will force the use of build-out strategies that can cost effectively light enough fiber to pass a large number of business buildings within a target area.

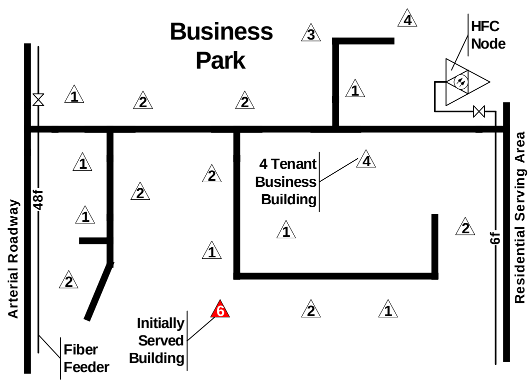
Determining how to extend fiber to business buildings is driven by where the buildings are located with respect to the existing fiber inventory, how many buildings are involved and how they are physically laid out. ***The good news is that the majority of the business buildings in an MSO's addressable market are within one or two thousand feet of the MSO's fiber plant.*** With respect to the fiber plant, business buildings can be broadly categorized as being on or off the fiber-feeder buffer or HFC node area as illustrated below.



Business Building Locations

Geographically, where businesses tend to cluster relative to the fiber is dependent upon regional circumstances as well as how the MSO chose to build the plant originally. In the majority of cases the primary fiber-feeder runs are located along arterial roadways which fortunately are also where most businesses are located. However larger businesses with more advanced communications needs may be more likely to cluster off of the feeder or node areas. Typically off-node clusters will present the greatest challenge in that the fewest possible spare fibers will be available to serve the cluster.

The number of business buildings in a cluster and their geographical layout can complicate how fiber will be extended, this is where selecting the right network topology can reduce complexity, cost and investment risk. The following example illustrates a combination circumstance where a small business complex is bracketed by arterial roadway on the left and a residential neighborhood on the right.



Business Park Example

A large distribution feeder cable runs along the arterial, while a small 6 fiber stub from another distribution branch reaches a lone fiber node. The business complex is composed of fewer than 40 businesses housed in a number of single and multi-tenant buildings. The building represented by the shaded triangle houses the initially targeted business subscriber. The simplest and lowest cost approach to extending fiber to the initial target location would be the allocation of two fiber-feeder strands that are extended directly to the target building from the nearest splice point. Such an approach is certainly low cost day-one, but quickly becomes a serious liability when the core business development objective is to sell services to other businesses in the area.

Ideally the task of extending fiber to the first business subscriber would cost-effectively position the MSO well for future sales within neighboring buildings without significant additional cost and without consuming additional feeder fiber. Unfortunately, circumstances are greatly complicated by the fact that the sale of business services rarely proceeds in an orderly fashion. Business opportunities arise in a nearly random sequence based upon existing subscriber service contracts and evolving subscriber needs and available services. Additionally, in each case the decision to serve an opportunity must be justified on its own return on investment (ROI) merits. Typically the ROI model for the first subscriber in an area will bare the brunt of the cost of extending fiber from the nearest point on the existing plant. In those cases where the physical route to the subscriber's building passes a number of single or multi-building clusters of business subscribers, as illustrated, the MSO may choose to augment the initial service extension, building out with additional fiber such that other businesses along the route can be easily provisioned for service as they are signed up over time; a common sense strategy, but one that increases the ROI risks and that has practical limits in terms of how many additional fibers can be extended and to where.

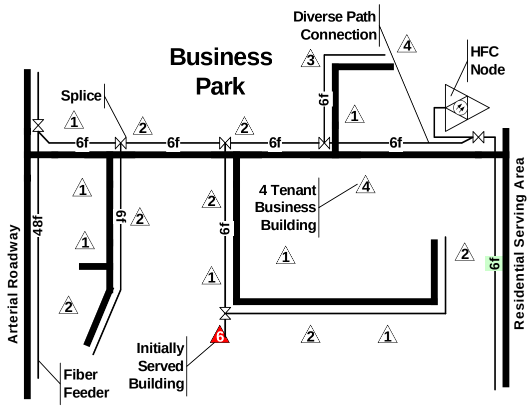
Once the decision has been made to extend fiber into a business building area it is very difficult to predict which of the remaining businesses could become customers and when. It will be to the MSO's advantage to pass fiber by as many buildings as budget will allow knowing that in a competitive environment service turn-up velocity will be a key to winning service contracts once they are up for renewal. Thus, once a service is sold service turn-up can be limited to installing a drop and terminal equipment. Both of which can proceed in a much more timely fashion than roadway construction.

Perhaps based upon prior knowledge and practice in these circumstances the shared fiber deployment approaches most likely to be initially explored are bus-star or star topologies such as PON and remotely switched Ethernet. In either case engineering challenges quickly mount, the following are just a few:

- How many buildings in the area are expected to house customers?
- How many fibers per roadway branch?
- Within budget can fiber be routed along each roadway in the complex?
- Where should fiber access points be placed?
- How and where should the fiber runs aggregate?
- Where is the fiber coming from, is the cluster too far from the host hub or headend?
- Is there sufficient remaining optical budget to reach all of the buildings?
- If an active star topology is used, where is the aggregating switch to be located and how will it be powered?
- Is there a solid record keeping system such that two, three or four years after bundles of fiber have been installed and wavelengths have been assigned will operations be able to quickly and accurately tap into the available fiber strands without disrupting existing services?
- Will service resiliency be required?
- Will existing customers tolerate the service outages that may be required to add new subscribers?

By contrast a ring based topology, particularly EAD approaches, offers several key advantages that greatly simplify or eliminate these issues. A ring approach eliminates all design variables associated with how many fiber strands and/or wavelengths to use and where. It is very likely that the same common set of strands will be used for the entire area. ***A ring also eliminates the need to know ahead of time where access to a fiber buffer will be needed. This is very important considering the fact that often business park developments are not fully mature and new buildings are being added periodically.*** Fiber rings are passive and EAD rings do not require field installed optical couplers or combiners. Additionally, all CPE optical connections are point-to-point greatly easing optical level concerns. Thus plant design considerations along with ranging considerations are greatly simplified. Since the same fibers are being used no matter where a subscriber is being added to a ring a simple color based fiber tracking methodology is all that need be followed, e.g. a four color coding scheme that identifies the east and west ring segments irrespective of location on the ring. EAD rings further simplify optical layer record-keeping by eliminating the need to track subscriber wavelength allocations. Finally, rings offer the added bonus of being able to offer resiliency in the form of diverse path fiber routing.

An example of how a ring topology can be used to address every business building in our business park example is illustrated below. Note the lack of centralized fiber aggregation points, outdoor active equipment and the ability to address all of the business park buildings with a simple six fiber buffer routed along each roadway. Fiber splice cases can be added arbitrarily for service drops as subscribers are added over time, deferring costs and simplifying attachments. Technicians need only know the east and west ring segment fiber pair color codes to successfully splice into the ring. However the wavelength allocations associated with an OAD ring must still be carefully tracked. If a diverse fiber path is desired for the feeder portion of this ring a diverse path connection can be made to the nearby HFC node's fiber stub.



Fiber Ring Access Example

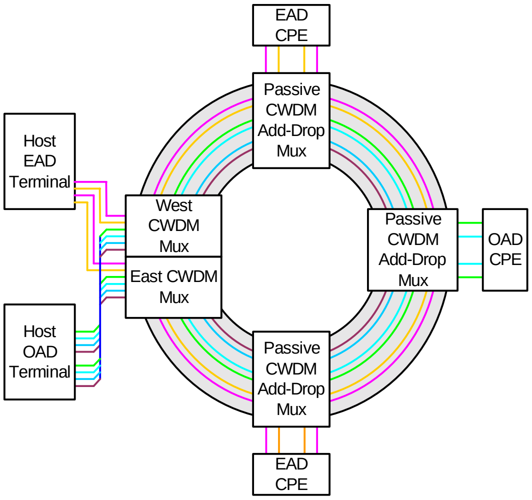
Engineering considerations aside, probably the most attractive aspect of using rings for business access is the overall reduction in deployment cost and business risk. ***Fewer components, simpler signaling and easier tracking lead to lower CapEx and OpEx costs, but the fact that a modest fixed amount of fiber strategically routed that can be accessed arbitrarily over time puts the MSO in a favorable position; one of being able to extend service quickly as opportunities arise, irrespective of take rates, building densities and geographical layouts.***

CONCLUSION

The development of business services programs will present MSO's with significant technical and managerial challenges that have little historical precedence. An integrated set of simple, clear and effective business development and technical strategies that leverage existing strengths and infrastructure will be critical to success. This requirement clearly must include fiber deployment strategies that maximize service delivery capabilities while minimizing complexity, cost and business development risks. To this end it has been shown why ring based access topologies should be seriously considered as a cornerstone to the MSO's business services program.

Two fundamental techniques for implementing fiber rings based upon optical or electrical add-drop functionality have been outlined and shown to offer common and unique properties that are largely beneficial, but can also present unique technical and operational challenges that must be effectively accommodated. Ring implementations based upon optical layer add-drop (WDM) techniques offer elegant physical layer means of extending private dedicated links to the subscriber premise that are immune to localized CPE failures. However these techniques encumber engineering, operations and management functions with difficult service extension and tracking challenges with little or no promise for an offsetting cost benefit. By contrast, ring implementations based upon electronic add-drop techniques greatly simplify deployment and management demands by supporting the automation of all service related management and tracking functions at the network management system level; enabling the normalization of how physical ring connections are made irrespective of where or when they are implemented.

A combination OAD/EAD strategy may offer a best of both worlds compromise, as illustrated below.



<u>Combination EAD/OAD CWDM Ring</u>

In this case two OAD ring wavelengths are allocated for EAD ring operation and are dropped into those business buildings where one or more small to intermediate business subscribers are located. The EAD ring's innate ability to aggregate at the CPE and the headend is highly scalable in this circumstance. Larger business subscribers who can afford access to a dedicated optical link can be hosted from the remaining OAD wavelengths. These subscribers are likely to be much fewer in number thus reducing scalability and plant management demands. This strategy allows the MSO to offer a enhanced differentiated high-end service to larger customers while at the same time easing plant scale and management issues.

<u>REFERENCES:</u>

[a] IEEE 802.17 Resilient Packet Ring Working Group, http://www.ieee802.org/17/index.htm

[b]Internet Engineering Task Force, Fast Reroute Extensions to RSVP-TE for LSP Tunnels, http://www.ietf.org/internet-drafts/draft-ietf-mpls-rsvp-lsp-fastreroute-02.txt

[c]IEEE 802.3 - 2002, "Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
Access Method and Physical Layer Specifications", Section 4, Link Aggregation, http://standards.ieee.org/getieee802/portfolio.html

[d] IEEE 802.5 – 1998, "Token Ring Access Method and Physical Layer Specifications", http://standards.ieee.org/getieee802/portfolio.html

[e] ISO 9314-2:1989 Information processing systems -- Fibre Distributed Data Interface (FDDI) -- Part 2: Token Ring Media Access Control (MAC), http://www.iso.ch/iso/en/StandardsQueryFormHandler.StandardsQueryFormHandler

[f] "FDDI Technology and Applications", Authors: Sonu Mirchandani and Raman Khanna, Copyright 1993 by John Wile & Sons, Inc

[g] "SONET, Second Edition" Author: Walter J. Goralski, Copyright 2000 McGraw-Hill

[h] Internet Engineering Task Force , RADIUS (Remote Authentication Dial-In User Service), http://www.ietf.org/proceedings/96dec/charters/radius-charter.html

<u>BIOGRAPHY</u>

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