INTELLIGENT CABLE DATA SERVICE ARCHITECTURE: ENSURING COMPETITIVE PARITY WITH OPTIMIZED CAPACITY

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Abstract

Cable has a ***"once-in-an-era opportunity"*** *to leap to the head of the class in Internet (and other information) services by optimizing and leveraging its bandwidth advantage in the delivery of data services. Cable's challenge is to deliver competitively-priced yet* ***"superior informational experiences',*** *to increasingly diverse customer communities, before Local Exchange Carriers (LECs) can realize returns on investments in more efficient local loop technologies (e.g., ADSL) and HFC overbuilds. The key to this opportunity is the development of an integrated cable data services architecture. Such an architecture, when implemented, would optimally leverage existing network assets while maximizing return on HFC capital expenditures, creating a data service environment with the broadest of market segment appeal.*

This paper explores key aspects of cables' architectural challenge. It first explores the potential rewards associated with achieving an optimal data services architecture. It then examines a data services architecture designed to optimally leverage cables' existing broadband assets, while maximizing return HFC investments. This architecture attempts to show how some latent (and generally un-used) HFC component features, might be combined with improved packaging (i.e., reduced form factor) of certain legacy LAN functions (expected in the very near term), to create a flexible data services infrastructure capable of supporting the broadest array of applications and related market segments

PERSPECTIVE

The deployment of Internet access and other data services capabilities over cable television introduces a whole new competitive dimension to the cable industry (and, we might add, just in time). These services represent the most promising near-term cable offerings for creating profitable new revenue streams, enhanced system valuations, and competitive parity against other local telecommunications companies. The importance of these services is further amplified by the market uncertainties associated with new entrants and emerging threats to traditional core cable entertainment offerings. After all, the future success of traditional cable and recent competitive entertainment services such as video dialtone, MMDS, LMDS, and DBS, depends entirely on the shifting consumer perspective re: how to spend leisure time. To surf, learn, and grow, or sit and risk mental atrophy.

Perhaps we shouldn't be so surprised at the Internet phenomena; after three decades of distributing information and information technologies, society is beginning to get hooked on the knowledge and potential opportunities that can be won via ready access to information, Access to the Internet represents a valuable "portal" into the largest and most dynamic global repository of humanly consumable information in existence. The cable industry has the unique opportunity to define a new and enhanced class of access portal using cable television networks, a portal that enables the Internet experience to take on whole new dimensions and entertaining attributes. The enabling of these new dimensions will, in turn, cause the Internet to respond with new experiences that take advantage of them. The players providing the most *value-enabling* portals onto the Internet will help shape the Internet's evolution by continually enhancing the potential of the Internet experience.

Cables' data-oriented opportunities are, however, accompanied by non-trivial architectural challenges associated with the deployment of robust, reliable, scaleable, and manageable data services, in multiple classes and quality levels, in an ever-changing technical and marketing climate. If cable is to effectively compete in the exploding data services space, it must embrace these architectural issues in such a way as to maximize the value of its present bandwidth advantage, across diverse customer communities, while maintaining the integrity of its traditional entertainment delivery capability.

With the steady advance of communications technology, and the continuing integration of computing into the telecommunications and entertainment infrastructures, cable can draw on an increasing array of advancing capabilities to embrace its architectural challenges. However, even with today's truly incredible arsenal of technologies at its disposal, the absence of key functions in critical areas still prevent the realization of the optimal high performance infrastructure. It is important to note that most (if not all) of the technologies needed to implement such a data service infrastructure already exist. Indeed, some of them simply need to be replicated and relocated within the infrastructure, while others are repackaged and deployed in ways possibly beyond their creators' visions.

Although some of the functional integration concepts envisioned may seem radical at first, they essentially represent traditional data networking concepts common to the traditional computing industry market, applied to cables' broadband HFC environment. When viewed in the broader context of today's convergence economy, an economy that is in no small way influenced by how and in what quantity we choose to package sand and glass (silicon chips), these concepts are not that unfamiliar.

Finally, this paper should be viewed as posing "what if' architectural questions to an industry already wrestling with a variety of changing forces, from new realms of opportunities, to new and very real threats beyond its control. These and other dynamics not withstanding, this paper advocates a proactive approach to the architectural challenges that stand in cables' way of delivering "superior informational experiences" to growing market communities anxious to participate in them. It is estimated that the Internet grows by some 25,000 users each day, with almost 22,000 of these users adding their own web page (one page every 4 seconds). With this as an incentive, and with the knowledge that we are for the most part simply exploring concepts that combine re-packaged legacy LAN functions with existing (but little-used) HFC features (versus having to invent new technologies), the context and thrust of this paper is established. Physical (electrical) issues such as ingress, common path distortion, laser clipping, power line hum, and so on, have been thoroughly analyzed by many others in a variety of quality works, These issues are the center of much debate throughout the industry and in several formal standards groups, and are not discussed in this paper. However, as important as these physical challenges are in the overall cable data services agenda, the value of their imminent solutions may be lost without a clear understanding of how best to deploy them.

INTRODUCTION

Most will agree that the cable industry's most definitive (current) competitive advantage over other data service and network access providers is its broadband spectrum, and the superior locally-deployed bandwidth it represents. A well-designed cable network *architecture* is the key to leveraging cable's bandwidth advantage.

A good architecture will leverage cable's bandwidth advantage for many years to come; a poor (or lack of an) architecture will likely sacrifice this initial advantage in the wake of poor reliability, contention-oriented service access denials, congestion-oriented poor service performance characteristics and related quality of service (QOS) issues. Problems of this nature would undoubtedly result in serious growth impediments and high customer attrition rates for cable-based data services.

The primary "data services" cable agenda in 1996 must therefore be to successfully overcome these architectural challenges in such a way *as* to achieve a *future-ready* technical posture consistent with long term prosperity in the data services space.

Many cable companies are already deploying there best estimate of what a hybrid fiber-coax (HFC) network should be. The absence of key formal technical standards, and other industry dynamics, are creating reluctance on the part of many cable operators to invest heavily in such an uncertain market climate. However, an expanding markets' growing appetite for higher performance information access, and a confidence that competing interests will certainly respond to that appetite with any performance improvements they can muster, creates a serious paradox for cable.

Should cable wait for a more stable technical climate while competitors' capabilities (and market shares) grow, or should it simply set course and weigh anchor with the knowledge that it may have to build a new ship while at sea? Would a cable architecture that ensured realization of maximum bandwidth efficiency and related market value be compelling enough to move cable forward with serious energy focused on its data services agenda?

It is probably fitting that, consistent with cables' traditional entrepreneurial spirit, it must pursue its data services architectural challenges in the most entrepreneurial of environments where new industries can spring up overnight, and traditional architectural concepts are constantly being tested and sometimes redefined. The very definition of information architecture itself is evolving. Before examining these challenges, a brief excursion into the nature of the reward such an architecture might bring seems in order.

PART I: THE POTENTIAL REWARD

The Nature of Association: A Look Back

In the early days of telecommunications, telegraph operators provided a service where the delivered value was a decoded message on a piece of paper. In this case, the service provider was the one with the telecommunications device. Then came the telephone, where the telephone company provided everyone buying voice service with a device called a telephone. Radio, and then television, marked the beginning of scenarios where user-owned devices played an active role in the delivery/consumption of telecommunicated information or other value. When we were all allowed to own our own telephones, then basic telephony joined the scenario where customer-owned devices in the home played an active role in the delivery of a telecommunications service. Next came the cable set-top converter, yet another device in the home, that greatly expanded the programming choices available to the viewer.

These devices became associated with the nature of the service being delivered and consumed, e.g., telephones became associated with voice services, the television with visual entertainment and news services, and the radio with audio entertainment, news, and other programming. The cable set-top converter became associated with greater *variety* in television content, and importantly, gave viewers far greater options with respect to control over what they watched on television.

The important point here is the *association:* people associate different devices with the consumption of different services (e.g., radio with the reception of audio entertainment, television with the reception of televised content, and so on). Both bounded (e.g., POTS) and less bounded (e.g., cable television) services have associated with them a device involved in the use of those services. The computing revolution, however, added a new twist to this "service-device" association.

Information *Manipulation* Association

People bought personal computers to do useful and/or interesting things with information, whether using a spreadsheet program, a word processor, and/or playing a game. Computers basically manipulate, transform, package, and present information at very high speeds. Storage and other limitations of affordable personal computers, and the need for people to exchange information electronically (i.e., Email, document exchange, and so on), fueled the concept of *networking,* making it possible to *access* remote information and even collaborate and exchange information with others in real time

, The phenomenal popularity of the Internet's World Wide Web has even spawned a challenge to the association of information manipulation with the PC; the new low-cost *Internet appliances* grabbing headlines recently are contenders for this association, although the PC's have a formidable headstart (i.e., 70 million plus PC households) to overcome.

Information *Access* Association

Since the telephone line represented the incumbent two-way media in and out of buildings and homes, the telephone modem naturally became the device associated with traditional data networking.

However, the steady evolution of computing, software, and networking around the markets' growing need for more and more sophisticated methods of packaging and exchanging information, **has led to an unprecedented opportunity for cable to *redefine* the device associated with *access to information*.** Visual information (e.g., graphics, video, imaging) has always been superior to mere words, with respect to the exchange of ideas and information (i.e., a picture is worth a thousand words). As information becomes more visual in nature, and is reliably delivered over cable networks, its consumers will very likely find it natural to associate this kind of information with the television industry.

Since the telephone system was designed around the 4 Khz wide voice-band, it contained its own built-in limitations re: useable bandwidth which, to the detriment of telephone companies, falls far short of the bandwidth needed to reasonably deliver today's popular multimedia information. The telephone companies, however, are not sitting still. Intense work on expanding the informationcarrying capacity of the local loop, both in compression algorithms and line encoding efficiencies (e.g., ADSL), are beginning to pay dividends as the telephone industry responds to cables' emerging high-performance data services threat. In addition, the LECs have announced plans to build out broadband networks to cover more than 30 million homes nationwide on planned expenditures of over $30 billion.'

The cable industry, on the other hand, has its own set of built-in limitations associated with the traditional one-way nature of cable networks, and the less sensitive (versus data) nature of the signals involved in the delivery of traditional cable entertainment programming. The development of bi-directional HFC networks and related 2-way active coaxial components go a long way towards eliminating cables' primary obstacles. But will HFC networks and 2-way components enable cable to win the battle for the markets' association of cable-based data solutions with the preferred method of accessing information? Perhaps, but more probably if cable-based information access represents a superior information *experience* regardless of whether that information resides on the Internet, Online service provider system, or on the office, hospital, or school LAN just a few miles down the road.

The stakes are high in the competition to earn the markets' industry association for data and information services, and the telephone industry has a running head-start.

Cables' Opportunity

In order to effectively compete with the telephone industry's' certain continued innovation and capital investments, cable companies must deploy data services capabilities architected to optimally leverage their local bandwidth advantage in the areas of

- maximum service capacity (user concurrency and system load),
- quality of service (minimized service disruption impact),
- ease of management (fault isolation), and
- maximized functional value/utility for both the data services user community as well as the cable operator.

In the author's view, cable's near-term success in delivering Internet access and other data services is a prerequisite to the market's acceptance of cable as a viable alternative for the many existing (e.g., POTS) and future complex services the Information Age is yet to produce.

PART II: CABLE DATA SERVICES ARCHITECTURE

As with any complex technical system, many instantiations of a variety of architectural approaches can be made to work in the delivery of data services over cable networks. In fact, existing data-oriented cable products, such as existing cable modems and related headend equipment, impose a good deal of system. architecture with their deployment. This is due largely to the current absence of formal standards for this type of equipment. These existing architectures are by definition product-oriented, and are limited in their context to a particular vendor's offerings, and its view of the problems to be solved.

While these early product-dictated architectures are important aspects of cable's thrust into the data services markets (i.e., they are available and useable today), they are only one element in the context of architectural thinking cable must consider in order to sustain any early data services success these products enable.

Background

When most people think of architectures, they think of an orchestrated suite of functional and interface specifications that, when realized through technology deployment, support the interoperability and interoperation of these elements towards accomplishing some meaningful goal that markets will find of value. Traditionally, architectural thinking in information systems design has concentrated on the physical and logical dimensions of the information system objectives. Interoperable hardware and software have long dominated architectural concepts.

As mentioned earlier, however, the all-transforming wave of information and information technologies sweeping over nearly every aspect of society demands that we expand our thinking with respect to the *scope* of information systems architecture. It is no longer sufficient to think about information architectures in terms of hardware and software interoperability among the components of a specific information system solution. The growing role across the board of information and its technologies is establishing new priorities for those that provide information access infrastructure, priorities that can transform existing assets into future mainstream wealth creation systems. This requires information access providers to create flexible service environments where the changing needs of increasingly diverse market segments can be accommodated with new applications, not just the Internet or other Online service. These applications must not be constrained by underlying architectural limitations that restrict access capacity to information repositories due to their location within the architecture.

Current Thinking in Cable Data Architecture

The prevalent thinking today in cable data architecture revolves around the HFC network with asymmetric bandwidth allocation favoring outbound over inbound spectrum (e.g., 30 Mb/s outbound versus, say, 1.5 Mb/s more or less inbound). In addition to all the known benefits of HFC networks (e.g., reduced amplifier cascades, improved signal quality, etc.) this thinking is rationalized as

- stretching the utility of scarce useable return spectrum,

- taking advantage of the “small request/ large response” nature of the way the Internet and other Online services are accessed,

- accommodating the subsplit design of the majority of deployed cable systems, and

- accommodating the performance limitations associated with troublesome return spectrum..

The well-known benefits of HFC networks, as well as the ongoing massive capital investments in HFC equipment by MSOs and LECs alike, suggest that this technology will continue to enjoy wide-spread acceptance and deployment. However, the market opportunities that may be sacrificed to the limitations imposed by asymmetrical data solutions should be thoroughly explored and understood before large scale deployment of technology, especially if the intent is to utilize this same technology to support services opportunities across all market segments.

Additional Thinking on Data Services

Were it not for the limited amount of return spectrum available in the majority of deployed cable systems today, the argument for the asymmetric allocation of this bandwidth would weaken considerably. Since there is no magic wand that can be waved to suddenly create more useable return spectrum or improve the quality of existing spectrum in predominantly subsplit systems, architectural methods that reduce system-wide contention for this bandwidth (and/or technical breakthroughs in return spectral efficiency) offer the only realistic alternative to asymmetric bandwidth allocation. Before addressing an architectural approach with the potential to overcome existing return spectrum constraints, it is appropriate to understand the potential importance of such an approach in terms of the market ramifications that may occur as a result of the use of asymmetrical technology for all data service applications and markets.

"If cable creates a [data] services access environment that supports only a hand-full of asymmetrically-oriented information services prevalent today, it is betting the proverbial farm that asymmetrical information applications will continue to be all a community will ever want or need."[2] Investment resources tracking the evolution of the Internet forecast that "the number of individuals with full Internet access will grow from approximately 20 million today to more than 400 million in ten years, with the greatest growth coming from the corporate sector as businesses move to put themselves and their employees Online" [3]. The important point here is that, **unless these businesses are planning to relocate their servers and storage farms to cable headend facilities. or cable operators are planning to pull fiber to most of these institutions as thev deploy HFC networks, the asymmetric bandwidth model will limit access capacity to this corporate information as a function of the amount of return spectrum asymmetrical connectivity devices can support.** This could be a serious impediment to the use of cable-based data services by the business communities as they look to cut costs and boost productivity through work-at-home scenarios and Internet-based marketing. In addition, when one considers the voluminous nature of the information generated by many of these commercial institutions (e.g., X-rays and EM1 by hospitals and medical labs, graphical product descriptions and promotionals from retailers and grocery stores, and so on), restricting access capacity to these potential data services customers may be an expensive proposition in terms of lost market share. Commercial use of the Internet (especially the Web) to

- enable better employee collaboration,
- market products and services,
- provide access to corporate information such as employee handbooks, standards, product literature, and
- manage and administer software updates and other Workgroup tasks

offer compelling rationale to consider architectural approaches and technologies that accommodate the limited return spectrum situation with high-spectral efficiency on return channels versus compromising the value and related appeal of cable-based data services to commercial segments.

It is also clear from the estimates of numerous industry sources that applications such as video-conferencing, and the rising popularity of multimedia content on the Web, will continue to drive up demand for bandwidth in both directions. A realistic view recognizes that virtually all current sources of Internet content (including web pages and other multimedia) are distributed server systems located somewhere other than cable television headend facilities. An architecture that offers the highest capacity access to only those server systems located within cable headend facilities, or directly off an Internet backbone, significantly limits the appeal of cable-based data services as an Internet access and local data transport mechanism.

Leveraging Available Technology

Virtually all the technologies necessary to deliver data over cable, *without* imposing the limitations of an asymmetrical bandwidth model, exist today. As previously noted, to accomplish this will require the creative packaging of some of this technology in combination with latent yet currently un-used capabilities available in some HFC technologies (see Figure 4).

Although many new offerings, especially in the cable modem space, are expected to be available in the late 1996/early 1997 timeframe, at 25,000 new Internet users a day, a lot of market share will likely go elsewhere in the interim if cable opts to wait for these offerings to become available and stabilize. In addition, the large majority of these anticipated new cable modems offer asymmetrical service only. While these products will certainly play a large role in the providing robust access to the Internet and other Online services, cable operators are encouraged to consider the current crop of modem solutions to establish an immediate market presence (and gain meaningful intelligence) in both consumer and commercial markets.

The large majority of currently available (and deployed) cable modem solutions provide surprisingly reliable symmetric services over existing coaxial and HFC cable networks. Although these currently available modems may not offer the super high-performance in the outbound direction as those expected later this year, they nevertheless provide as much as 10 Mb/s symmetrical performance *now*, with further improvements expected as these products continue to mature. Not only does currently available technology enable cable's immediate entry into the data services space, its symmetrical capabilities should be especially appealing to commercial customers (e.g., ISDN and dedicated circuit users) hoping to utilize cable's superior capacity to facilitate work-at-home programs, enable employee collaboration, and market products and services on the Internet *now.*

The Challenge

Before exploring a viable architecture for cable-based data services, it is important to review primary architectural objectives, and the challenges that must be overcome to accomplish them. Our primary architectural objectives are to

- leverage cables' superior bandwidth capacity (relative to traffic load) while maximizing *access probability* and sustained session *performance through-put,*

- enable delivery of robust data services, in multiple classes and at different quality of service (QOS) levels, that support the applications and needs of as many market segments as possible,

- deploy *manageable* technology with maximum cohesion (functional isolation) and minimum coupling (inter-function dependency) to accommodate anticipated changes in available technology, and importantly

- deploy *profitable* solutions that can be efficiently and inexpensively transformed by the still uncertain macro and micro trends and forces the "infoconomy" is yet to exhibit and/or create.

Rationalizing a Model

Just as the arrival of the Industrial Era brought with it new thinking about the nature of commerce and social agendas, giving rise to such concepts as assembly lines, mass production for mass markets, and rapid urbanization, the creative challenge accompanying the infoconomy is about to sweep over us like the tidal wave it is. If we thought the move from the farm to the factory was significant, the rise of intellect over muscle that is rapidly taking root around us will make the farm-to-factory shift seem like a momentary preoccupation with human materialism.

Information technology has, in its relatively short existence, grown from a simple tool in the game of business, to the game itself. The plow has become both the field and the crop, where a persistent rain of creative thinking falls on mankind's' experiments with sand and glass, yielding crops of new perspectives on not only *how* we do things, but on *what* we do. And with the disparity in the distribution and use of information technology around the world, the infoconomy wave will produce different effects in different places at different times, giving it many meanings to many different communities.

As different as the fast-paced assembly line was from the season-long cycle from seed to crop, the Intellectual Era upon us will be far more profound. New entrants and competitive offerings call for adjustments in strategy. When whole new industries, methods of commerce, sovereign relations, and human priorities are created and transformed by

- the changing commercial and social significance of Information Age phenomena like the Internet and the World Wide Web, and

- the changing climates of various horizontal and vertical market segments.

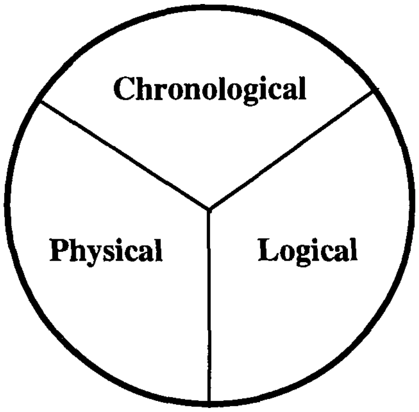

Figure 1. Architectural Thinking in an *Infoconomy*

the combination of sand, glass, and innovative thinking, it's time to invent new tools and adopt new perspectives consistent with that kind of world. The concept of an architecture is a good place to start.

Figure 1 depicts a perspective on an architectural model that is both simple and compelling. It suggests an expanded definition for information systems architecture that incorporates a temporal dimension in recognition of

- the increasing amount of information available about information technology (for infrastructure planning),

- the growth of ED1 and its implications (on value chain and other strategic analysis),

- the central role information and its technologies now play (at the macroeconomic and geopolitical levels),

The elegance of this architectural model lies in its comprehensive simplicity. While traditional architectures have always embraced the logical and physical dimensions shown here, there wasn't captured information about temporal events to attribute any significance to it as an architectural consideration. The addition of the chronological dimension acknowledges the increased role of information technology in nearly everything any of us do, the increased predictive and planning capabilities it endows us with, as well as it self-perpetuating nature. Figure 2 provides a more detailed view of the kinds of functions that lie within each dimension of this architectural model.

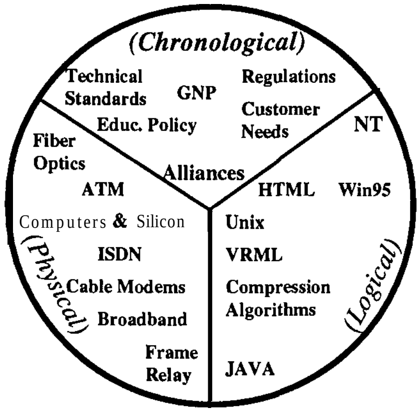

Figure 2. A Few Architectural Components

The key differentiator between the above architecture, and traditional architectures, is the presence of a chronological dimension. This is in recognition of, and respect for, the transforming central role information and information technology is increasingly playing in every facet of society from global commerce to entertainment, sovereign relationships to politics and social priorities. In other words, the *permeation* of networked information and information technology throughout the fabric of all these commercial, social, and institutional segments is creating increasing opportunity to include temporally-oriented forces, processes, and events in our architectural thinking. As this permeation continues across the board, can anyone afford to ignore the potential for linking these chronological issues into our automated information? Considering the pace at which this “info-permeation” is evolving, we are compelled to examine the possibility of making room for the implications of value chain analysis in our core business and technical architectures. With this architectural context in place, we can now explore an architectural approach for cable-based data services that embraces all three dimensions.

A Cable Data Architecture

“A network must be both flexible and reliable enough to allow for future services”.[4] The goal of the architecture pictured below is to profitably leverage all the capacity and performance capabilities of a 2-way HFC cable network, supporting as many market segments and applications as possible. This must be accomplished without compromising delivery of entertainment, while accommodating known cable characteristics such as the scarcity of quality return spectrum in most plants, the shared nature of the cable network medium.

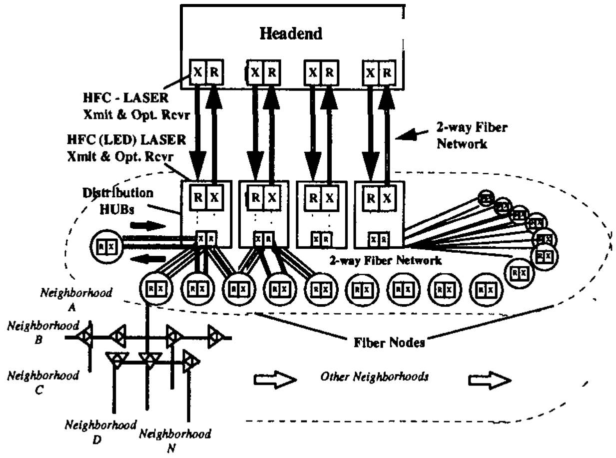

Figure 3. A Typical Cable HFC Architecture

Figure 3. shows a typical HFC implementation utilizing a popular hierarchical approach (e.g, master headend, distribution hubs, fiber nodes, and feeder coax). (Hub-to-fiber-node ratios shown are simply for illustration; real implementations have been found as high as 1:40. Amplifier cascades counts are typically 5 or less.)

In order to maximize available capacity across an entire cable system, while minimizing contention for that capacity, routed segmentation of the cable network is required. Routed segmentation architecture requires special packaging of some existing router, cable modem/bridge MAC/PHY layers, and frequency translation technologies, as well as the utilization of frequency stacking capabilities available in some existing HFC fiber optic technology. A fiber node capable of frequency stacking, combined with resident routing, cable bridge MAC/PHY, and frequency translation functions introduces a new class of broadband data communications device called a "SPRouter™" (for Spectrum Parallel **Router**). Figure 4 below a possible SPRouter implementation.

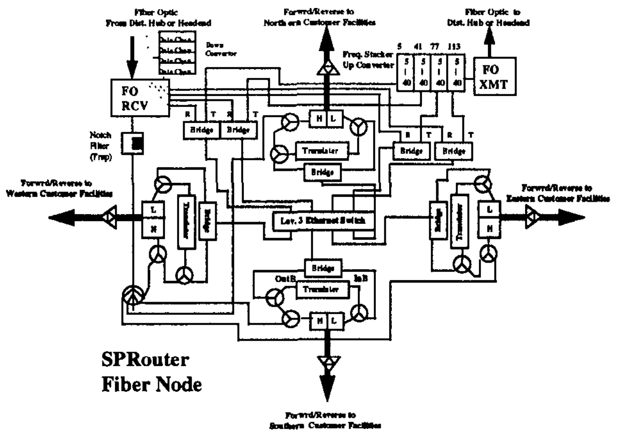

Figure 4: A APRouter Implementation

A *sprouter-bused* (routed segmentation) cable data network takes advantage of recent developments in fiber node technology (frequency stacking) and router function siliconization (i.e., router chips). The frequency stacking capabilities inherent in some recent fiber node implementations would be used to simultaneously transport (i.e., in parallel) the 5 to 40 MHz return spectrum, from each physical neighborhood feeder network, back to distribution hubs (DH) or headends (HE) for further routing. Emerging router chips would be useful in constructing DH or HE resident routers to accommodate the parallel networks created with the SPRouter approach.

The challenge in implementing a sprouter-based network is the need to locate router and other "LAN-defining" equipment (e.g., frequency translator, MAC/PHY layer modem/bridge device) functionality as close as possible to each physical neighborhood feeder junction along the cable distribution network. In order for the optimal implementation of this approach to be feasible, a low-cost router chip, combined with an intelligent MAC/PHY cable modem device, would be required that could be integrated into two-way trunk amplifiers, line extenders, and fiber nodes. However, until market demand (characterized in terms of data traffic analysis, specific applications usage, customer expectations and requests, and so on) proves that an investment in sophisticated trunk amps and line extenders would be warranted (and rewarded), "neighborhood size" cable-based LANs would be premature. (If cable acquires significant data services market share in high densities, it would not be surprising to see developments in this area occur.)

In the interim, however, many of the pieces exist to create routed LANs out of individual fiber node coverage areas (i.e., neighborhood groups). In addition, this approach would take advantage of spectrum stacking capabilities already available within existing fiber node technology, and the use of an intelligent switching capability at distribution hubs and/or headends. Fortunately, silicon-based router functionality is nearing availability. This will create opportunities to at least explore other related issues (e.g., weather-proofed enclosure, powering, space, etc.) associated with packaging router functionality within key active components.

The SPRouter approach requires complimentary functionality at the DH or HF. Figure 5. shows the DH or HE-based SPRouter that provides the functional counterpart to the SPRouter Fiber Node shown in figure 4.

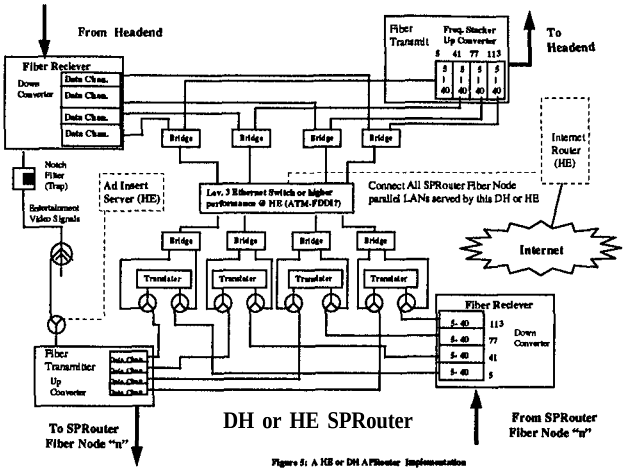

Figure 5: A HE or DH APRouter Implementation

This effect of a SPRouter network is the creation of a number of distributed LANs interconnected by the cable network where locally-destined traffic (i.e., within a LAN) is contained, and only remotely-destined traffic traverses beyond a LANs' boundary router.

The benefits of this approach are numerous:

1. More customers served by a cable system can engage in more locally-oriented bandwidth-intensive applications (e.g., a home to neighborhood school conference).

2. System-wide traffic is reduced to only that traffic needing (based on router decisions) to traverse the entire system in order to reach its destination (e.g, a home office to a corporate LAN, or an Internet user to the Internet access portal).

3. Each distributed LAN can utilize the same highest-quality return spectrum.

4. Each neighborhood LANs receive only the data traffic (from DH or HE level) destined for it by router decisions.

5. By integrating intelligent (level 3 switches) and modem/bridges within the DH and Fiber Node architectural roles, cable's data services delivery capability can easily take advantage of other technologies (e.g., Fast Ethernet, FDDI, SONET) as they become available and cost effective.

CONCLUSIONS

An intelligent cable network architecture, such as the SPRouter concepts described above, will help maximize cable's broadband spectrum bandwidth advantage by leveraging the functionality of typical HFC system-wide active devices and data equipment (modems, translators, switches/routers) relative to their role in the delivery of data services. This architecture identifies and maps minor (and reasonable cost) enhancements to mainstream cable network active trunk devices (e.g., fiber nodes) that will, when integrated into the functionality of an overall data service delivery system, transform the typical HFC cable network into a competitive weapon for the industry re: the optimized delivery of concurrent data and entertainment services. Importantly, the proposed device enhancements and system roles are technically feasible today, with many of the features that will be leveraged already latent but under-utilized in existing devices.

As stated at the beginning, one of the primary goals of this paper is to stimulate "outside the box" thinking among cable operators and technology providers. BY deploying networks that are capacity-optimized for data services, the cable industry will create a formidable challenge to competitors who would take advantage of any HFC capabilities not leveraged by the cable industry. As new technologies (e.g., ATM, others) become available, and as HFC systems evolve, cable must continue to strive for architectural approaches that leave little room for improved efficiency. With the stakes being what they are, and likely to get higher, why leave competitive advantage un-exploited?

Cable modem solutions are, indeed, a necessary part of cables' data services agenda, and their increasing availability is an important aspect of the challenges cable faces. However, cable's thrust into data services involves much more than the right cable modem. Cable must consider infrastructure enhancements to address the complete context of necessary functions like help desk support, data archival and storage management, billing services, software version control and licensing management, routing table management and domain administration, server performance tuning and system optimization, to name but a few. These and a variety of other issues must be considered when seriously contemplating provisioning Internet access and other data services. It is through the efficient use of information in all facets of delivering Internet and data (or any other) services that competitive advantage will be determined.

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[1] J.P. Morgan Securities Inc.; T. Savageaux, Equity Research, November 28, 1994, p.14

[2] A Case for Symmetrical Bandwidth; T. Wright, Convergence Systems, Inc.; Proceedings of the 1995 2nd International Workshop on Community Networking

[3] Institutional Research; Robertson, Stephens, & Company; The Internet Age, December 20, 1995, p.2.

[4] Considerations for Development of Existing CATV Networks for Future Telecommunications Services; D. Gall & P. Brooks, Time Warner Communications; 1995 NCTA Technical Papers