The All Fiber Scenario

STG1: Follow-on to the IEEE-USA/Cornell Workshop

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One of the most effective approaches to scenario mapping is the one that assumes a plausible outcome and works backward from the target date and provides an "explanation" for the "events" through which that outcome came about. That is the approach of this paper. We combine the scenario approach with the tool of concept mapping (see Figure 1 p. 3) to facilitate the explanation.

As we look backward from the year 2010, we seek to explain how it is that the all-fiber networks (AFNs) at the lower far right of Figure 1 came to be the dominant elements of the current telecommunication infrastructure. We are well aware that there is a vigorous wireless infrastructure in place and near-ubiquitous wireless communication taking place. But we know that today in 2010, only the bandwidth available through full fiber connectivity is adequate for the most powerful applications.

Given an additional global imperative -- connectivity with mobility (CWM) -- pervasive wireless connectivity also is a surviving component of today's infrastructure. It is identified by its acronym CWM (upper far right). It coexists in complementary fashion with the AFN by providing CWM (“edge” connectivity) while the fiber provides that which cannot be made available with mobility, including "core" infrastructure for both.

The focus of much "cocktail party conversation" today is the dispute about which of the two fundamental aspects of the infrastructure of 2010 is the dominant aspect. Individuals supporting CWM greatly value the strengths of their mobile “control device” -- and they won't leave home without it! Their faux-adversaries point to those elements that cannot be mobile, and which must be served by bandwidths available only through AFN fiber connectivity, well beyond the capabilities of mobile wireless. Their favorite phrase is, "The Infrastructure of the Infrastructure is Fiber." With this they hope to end the discussion. This paper is an exposition of "how these things came to be.”

The Beginnings

Figure 1 presents the major elements in the evolution of the telecommunication infrastructure that we enjoy in the year 2010. They originated in large part from unintended consequences. Almost paradoxically these origins included an early wireless challenge (shown at the far left of the map) -- that of Direct Broadcast Satellite (DBS). The challenge was to one of the early players, the cable TV suppliers, whose technology is now merged with others in the modern infrastructure.

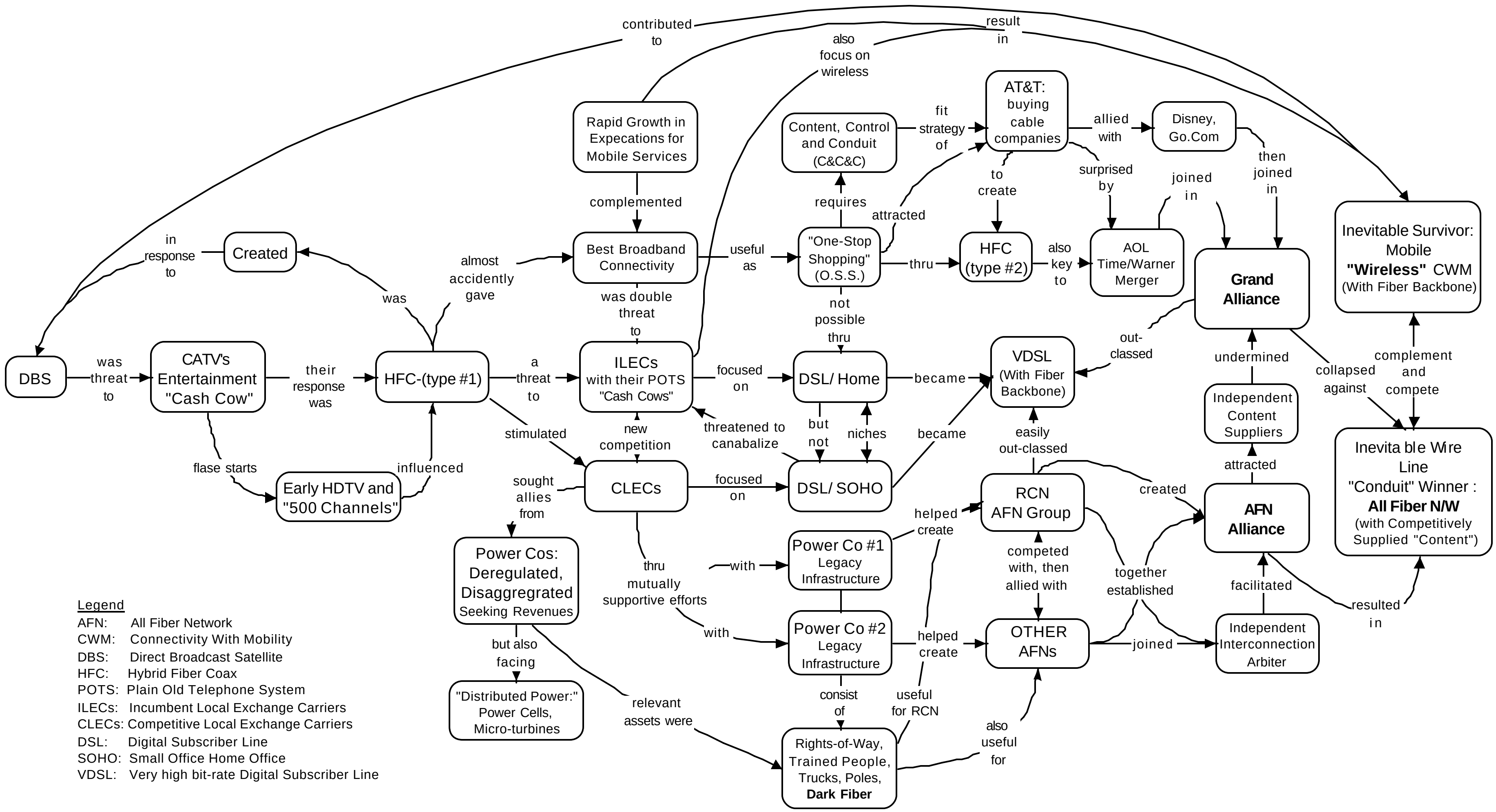
As shown in Figure 1, early in the 1990's CATV (Community Antenna TV) suppliers found themselves losing customers and revenues to vendors of DBS television services. The DBS system provided more channels picture quality superior to that available through standard Cable. The response of the CATV providers was to develop and begin to deploy what has come to be known as the “HFC” (Hybrid-fiber-coax) network. These hybrid systems incorporated optical fibers between a "fiber-node" (FN) and the system headend (HE), while continuing to make use of a coaxial-loop with drops generally to 500, but also to as many as 2,000 homes (see Figure 2, Appendix).

The (too) early HDTV (High Definition Television) craze also hit, then faded. After much controversy, American equipment firms had formed a "Consortium" to create the standards for digital HDTV in the US, but implementation languished. Nonetheless, it was recognized that the HFC would have to be capable of transmitting HDTV to its viewers. A second phase of market pressure further influenced the design of the HFC networks, this one from the programmers eager to get their services in front of cable customers, by filling up "500 TV channels". Much was written about the coming convergence of telecommunications, entertainment, and even education. All these would require two-way digital connectivity. This multi-media convergence is the first of three types of convergence allude to in this "future history" of the evolution of the Network Infrastructure.

The Joint IEEE-USA/Cornell Workshop

The Evolution of the Telecommunications Infrastructure Over the Next Decade

A Scenario: THE INFRASTRUCTURE OF THE INFRASTRUCTURE IS FIBER



Legend
- AFN: All Fiber Network
- CWM: Connectivity With Mobility
- DBS: Direct Broadcast Satellite
- HFC: Hybrid Fiber Coax
- POTS: Plain Old Telephone System
- ILECs: Incumbent Local Exchange Carriers
- CLECs: Competitive Local Exchange Carriers
- DSL: Digital Subscriber Line
- SOHO: Small Office Home Office
- VDSL: Very high bit-rate Digital Subscriber Line

For Background, Visit: www.johnson.cornell.edu/faculty/mcadams/workshop

Figure 1.

Consequences Intended/Unintended

Almost accidentally, it dawned on cable network suppliers that this HFC architecture offered the best broadband connectivity (to anything and everything) within the feasible set of the immediately-available options -- and that it could be made bi-directional.

As we note in the upper-central portion of Figure 1, the HFC's attractive broadband connectivity offered the opportunity for "one stop shopping" (OSS) for all elements of the impending convergence. This, in turn, proved to be very attractive to AT&T (upper right, mid-map). AT&T was finding itself under increasing competitive pressure, not only from MCI-WorldCom and Sprint, its main long distance competitors, but also from new players with low cost, global connectivity for long distance telephony and other services.

From the time of the break-up of AT&T (mid 1980's), all long distance carriers were burdened by the need to pay access fees to Incumbent Local Exchange Carriers (ILECs). These latter carriers principally consisted of the Regional Bell Operating Companies (RBOCs) created by that break-up. The ILECs had visions of reentering the market for long distance telephony while maintaining their monopoly position (and flows of access fees) from all those seeking to reach the users whose connectivity they monopolized. At their peak, access charges had represented a third or more of many RBOCs' gross revenue.

The greatest attractiveness of the HFC to AT&T was the near ubiquity of the nation's CATV infrastructure. Those networks "passed" within connecting-distance of approximately 97% of American homes and could be deployed reasonably quickly to provide connectivity to businesses of all sizes. They also offered the opportunity to by-pass access fees.

AT&T and Sprint were the two companies that made most clear their intention to reach end users with an OSS-offering that would include local and long distance telephony as well as data and video services. AT&T also recognized the value of broadband connectivity as a low-cost means to deliver these services to the home. It set out to buy cable TV firms and convert them to HFC carriers (Figure 1, upper-mid, right).

In 1998-99 AT&T moved rapidly to purchase cable systems of its own. Time Warner had built a cable-modem high-speed access service called RoadRunner, and was planning to launch cable telephony service through Time Warner Telecommunications. MediaOne Group had built a similar organization called MediaOne Express, that was merged with RoadRunner in 1998. And a consortium of Tele-Communications, Inc. (TCI), Cox, Comcast, and Rogers Cablesystems (a Canadian company) had developed and launched AtHome. Each of these companies had its own plan for tiers of service offerings on their HFC systems, although they all generally included analog and digital television services, cable-modem Internet access services, cable telephony, and video on demand. AT&T announced an agreement to purchase TCI. Two months later, Comcast announced that it was purchasing MediaOne Group; but AT&T soon announced an even better offer for MediaOne, moving Comcast out of contention. Included among the acquisition terms for MediaOne, were arrangements for AT&T's cable-telephony service with Comcast, as well. AT&T was on the move.

Later in 1999, however, AT&T announced that its HFC upgrade costs to provide telephony on former TCI systems would be greater, and would take longer -- perhaps two years longer -- than originally expected. AT&T and other operators had to provide circuit-switched voice over cable until the technology for packetized-voice was perfected and standards were established. Nonetheless they were committed to packetized-voice.

What had started as a response to the improved TV images offered through DBS, now was recognized by all players as a potential threat to the ILECs, all of which enjoyed monopoly returns from their plain old telephone service (POTS) (mid-map). In the context of “convergence,” the ILECs also recognized their need to try to match the broadband capabilities of the HFC in the hands of the cable-players in general, and AT&T in particular. Both their current and their future revenues were at risk (mid).

The ILECs Respond

Even before the year 2000, the ILECs found it necessary to recognize the "handwriting on the wall" by deploying DSL (digital subscriber line) over their copper-wire plant. At 1.5 Mbps, DSL was a reasonable competitor to the early offerings of broadband connectivity through the RF modems of cable companies. The ILECs, themselves, faced a dilemma since their highest priority was to protect their "cash cow" of voice services (mid-map). Despite the rapid growth of data traffic across the telecommunications infrastructure, the bulk of their revenues -- more than 90 percent in some markets -- came from voice services.

For example, in the early period of DSL deployment, the ILECs were very reluctant to provide DSL to what has become known as the "SOHO" (Small Office, Home Office). This was, indeed, rational from the point of view of the ILECs, given that "real" business customers were already served by high-margin T-1, and even T-3 tariffed-services. The T-1 tariffs had been as high as $1,500 per month in some urban markets, but had gradually declined to $500 and threatened to fall to $250 and even lower. Comparable DSL service, however, was priced at $99.95/month for business users (and half of that for asymmetric service to residential users), a fraction of the charge for the T-1 services. On the other hand, home-customers for DSL were new customers to the ILECs; these customers represented new revenue to them and thus were the DSL-targets for the ILECs (mid-mid).

The CLECs

The Telecommunications Act of 1996 greatly facilitated the emergence of the new telephony players, the CLECs, or Competitive Local Exchange Carriers (Figure 1, lower-left-mid). Many of these firms were small startups struggling to compete with the ILECs while initially using the facilities of the ILECs to reach local customers. CLECs found it very attractive to serve the SOHO as well as the home user market, both of which segments represented new revenues to the CLECs, and neither of which segments were being strongly pursued by the ILECs. The SOHO customers were likely to be the revenue backbone for the CLECs' emerging DSL service; these customers could justify their broadband expenditure from the business in which they were engaged, saw Internet access as a critical resource for the business, and thus were relatively indifferent to price.

By the end of 1999, there was at least one CLEC in each major US metropolitan area. Many were providing competitive voice services as well as DSL Internet access; most of their customers are small and medium-sized businesses. The CLECs that provided alternate local connectivity for the end users became targets for access fees from the long distance players. In some markets, data-only CLECs, called DLECs, or Data Local Exchange Carriers emerged. DLECs' business models are similar to CLECs' – rent the local loop wire from the ILEC, and provide bundled services to business-oriented customers.

Some CLECs also offered fixed wireless services to businesses. As noted on its web site at the turn of the century, a leading CLEC, Winstar stated,

> "Today, Winstar can reach …80% of the business market in the US….Winstar has acquired the most local radio spectrum of any broadband provider. Our Wireless Fiber^{SM} services provide fiber-quality transmissions at speeds up to OC-3 [155 Mbps]."

This bandwidth greatly exceeded that available through DSL. The concept used, LMDS, local multipoint distribution service, appeared and appears promising for the future, including a likely role as a substitute or complement to fiber installations in particular areas.

Evolving Internet Usage

Historians have noted that even before 1999, the way firms -- especially American firms -- did business was totally transformed by Internet access connectivity that did not exceed 56 kbps for individual consumers. AOL, the largest of the Internet players, had participated with its dial-up compatriots in providing millions of users with access to the Internet. What came to be known as e-Commerce was facilitated by these firms. A new acronym emerged -- "B2C," for Business to Consumer e-Commerce.

By far the greater, more rapidly growing form of e-Commerce was known as "B2B," for Business to Business e-Commerce. B2B was typically conducted through virtual networks called "Extranets". Frequently, these were implemented by commercially-focused ISPs that sold private, secure, IP networks to business customers. The physical facilities for these networks were typically copper T-1 circuits leased from the ILEC, but sometimes from the CLEC or DLEC.

Conflicting Choices

At the end of the 1990s, AT&T was in a difficult spot. It had taken contradictory positions on important issues. The cable industry had fought hard for many years to resist being called a "common carrier," while prior to its acquiring TCI and MediaOne, AT&T had fought hard to ensure that access to the ILEC networks was on "fair and reasonable" terms. Then, AOL attempted to invoke its political clout with the FCC and the courts to force AT&T to open its cable networks to AOL and its 20 million semi-captive users on "fair and reasonable" terms through a policy dubbed "open-access." Michael Armstrong, Chairman of AT&T, fought even harder to block AOL and others from achieving such access to its cable systems.

The AOL-Time Warner Merger

The merger between AOL and Time Warner (upper-mid-right), announced January, 2000, ushered in a new era of bandwidth availability for public Internet access for AOL, not just to consumers, but also to business, industry and government. AOL had struggled for years trying to free itself from the tyrannies of its "dial-up prison." The acquisition of Time Warner facilitated true broadband access directly into the cable market, providing quality connectivity to AOL's customers. With its purchase of Time Warner, AOL became an operator of its own HFC network (Time Warner Cable). But at the same time, with the closing of the MediaOne merger, AT&T became a 25 percent owner of Time Warner Entertainment. With the AOL-Time Warner deal, AT&T then-owned a stake in that merged-entity.

Armstrong "crowed" that the open-access "nonsense" would immediately go away, given that AOL, Time Warner, and AT&T now had "the same interests." Armstrong stated that AT&T at that point sought to be “the world’s leading communications company,” while he perceived that AOL-Time Warner sought to be the world's leading supplier of “content” for entertainment and news; objectives that were complementary to those of AT&T. But both needed ubiquity.

The "Grand Alliance" Emerged

As history shows, it was but a brief period before an alliance was created among the giants. Prior to allying itself with AOL-Time Warner, however, AT&T had created its own alliance with the Disney “content” conglomerate. Disney flouted ABC-TV, the GO Network and Portal, ABC News; its sports network ESPN; as well as its entertainment “brands;” as enticements to AT&T. AT&T touted its own emerging HFC broadband access systems. The coming together of all these players became known as the "Grand Alliance” (GA). Independent HFC network operators hurried to join, but many content suppliers were effectively excluded or economically crippled by the fees the GA required for use of its "HFC-conduit."

Digital (IP) telephony was deployed in earnest by the cable operators at this point, shortly after the turn of the century. It was delivered through the HFC, now equipped with two-way-technology supporting significant broadband connectivity both to the home and to small- and medium-sized businesses. Within the GA, AT&T focused on telecommunications infrastructure strategies, soon providing high bandwidth IP telephony and ubiquitous, low cost video conferencing for business, industry and individuals, as well as multi-media access for all users.

GA's Impact on ILECs

The Alliance’s HFC facilities provided connectivity to the homes of the bulk of the nation’s users and broke the back of the local access monopoly of the ILECs. The DSL deployments of the ILECs had proven capable mainly of user-initiated, interactive content that was essentially local telephony and fax services plus Internet access with limited “video-streaming.” The ILECs continued to pursue wireless services (mainly cellular), supported by an owned or leased fiber optic infrastructure. This infrastructure also propelled these players into long distance telephony and through various alliance partners, provided them with global telephony-reach.

Unfortunately, the plethora of players and the huge magnitude of the available fiber-backbone and global bandwidth, combined to drive the revenues from long distance telephony (and much of the local telephony-connectivity) down to the marginal cost of the services, a level that was very close to zero. The ILECs had carried their fight to participate in the long distance arena to the point that they achieved "success" -- just as long-distance revenues were being competed away.

Strengths of the HFC-Network

The GA was based on hybrid-fiber-coax (HFC) connectivity that made the convergence of data, video, graphics and voice ubiquitously available. The hybrid-fiber-coax network turned out to be a remarkably flexible and efficient technique for meeting the demands of cable subscribers for increased capacity. Cable-modems were provided only when users contracted for broadband services; new fiber nodes were introduced only in those areas where demand supported them; only in those areas where new and enhanced services were demanded, were such services provided. It was an “earn as you go” system.

To the overwhelming advantage of AT&T and the GA, there were a number of pleasant surprises inherent in the HFC implementation that had not been well understood by organizations offering competing technologies. Conventional wisdom had assumed that penetration by HFC would be severely limited by congestion, especially in the return (or "up-stream") channel. But competitors appear to have ignored the system's capability for splitting the number of homes served by the coax-ring from a given fiber node. As things turned out, careful management of the system went well beyond the avoidance of congestion to provide rapidly enhanced bit-rates in response to increasing demand. The HFC turned out to be an "increasing returns" technology!

Soon this hybrid architecture appeared close to a position of dominance. DSL deployments proved to be incapable of making the LECs effective competitors to HFC-based broadband offerings. Even today, in 2010, the most advanced DSL can provide less than 100 Mbps per customer, while the HFC network can provide bandwidth in the Gigabit range. The lower-cost alternative -- the HFC infrastructure -- completely overshadowed the best efforts of the ILECs seeking to use their obsolescent, legacy, copper-plant in the new world of telecommunications convergence (Figure 1, upper- right).

Fixed Wireless

On the wireless side, rapid development took place through "fixed-wireless" technologies. Toward the end of the decade, these technologies permitted 622 Mbps to the home. Fixed-wireless did provide the CLECs an alternate path for Internet telephony, helping to undermine the prior monopoly position of the ILECs. The bandwidth available through this technology came to exceed that available through DSL by a factor of six or more. Nonetheless, for bandwidth-intensive applications it was not a match even for the HFC. It is clear that the virtually infinite bandwidth available through an "AFN" is not approached by the best that fixed-wireless can do (see Table 1, below).

The GA business plan was hailed by Wall Street. It had its now-integrated high bandwidth "conduit" available to virtually every end user throughout the country. From its secure base of conduit owned by the Alliance partners, the GA offered the "content" created by its key members, Time Warner and Disney, that together had struck informal agreements to be complementary, rather than competitive, in their offerings.

The GA's Problem

A superior broadband system was quietly incubating largely among new players during the period of the rapid movement toward likely "total victory" by the GA. These were the All-

Fiber Network players (AFNs). Their technology was based on DWDM: dense wavelength division multiplexing with the rapidly escalating bandwidth capabilities shown in Table 1.

Table 1: Bandwidth Possible Through an AFN

	September 1999	January 2000
Bandwidth per wavelength (bw/wl)	80 Gbps	160 Gbps
Wavelengths per fiber (?/f)	200 ?	1,020 ?
Fibers per trunk (f/t)	300 f	300 f

These bandwidth capabilities of fiber implied that as early as 1999 an AFN could support two to five Gigabits to each desktop in its region if it used plastic fiber for the final connectivity-link. If optical fiber were used for the final link (at somewhat higher costs), the system could support 125 Gigabits to the desktop. This spectacular level of connectivity dwarfed that available, even by the end of the decade, through any competing technology!

Paradoxically, the AFN players had been thrown together by the very success of the GA; the seeds of the AFN's successful future had been nurtured by the strategies and tactics of the GA. But, before we explore these factors, we must visit the industry of the former "power utilities."

Further Complementary Change

The rise of the AFN had been facilitated by an unintended consequence of the deregulation of the power utility industry (lower-mid-left). As the result of deregulation, the integrated regional monopolies of the power utilities had rapidly disaggregated. Power generation was spun-off by these firms into a competitive market of its own. A second level of disaggregation occurred with the power grid. The then-competitive structure of power generation fed, and continues to feed its electricity into the grid for transmission to the remaining legacy-player, the power distribution entity. It is through this latter entity that the power-supplier "selected" by end users from among the many competitive suppliers, delivers power through the grid to the end user.

The legacy infrastructure of these distribution entities (low-mid) consisted of many elements. It included the power poles and power conduits; the rights of way -- not just to the home, factories, and offices, but essentially to every building in each territory -- plus the trained crews with their trucks capable of rapidly and inexpensively deploying fiber through the rights-of-way virtually "to-the-curb" in proximity to every building in the territory. Most power companies had installed fiber sufficient to manage their own businesses; many also had significant amounts of "dark fiber" available for alternative uses.

Not only had the power monopolies disaggregated into these three elements, but also the era of distributed power generation was just emerging, (low-left). The fuel cell and the micro-turbine were just reaching economic feasibility. Major players were committing themselves to their production. Through serendipity, the automobile industry of the US found itself outdone by the then-Japanese auto companies in the early competition for the very-high-mileage vehicle. US firms recognized their need to leapfrog. The element that would permit the leapfrog was the fuel cell. In turn, the leapfrog would assure future demand for fuel cells.

Both General Electric and Allied Signal had committed huge resources to these distributed-power-generating elements, the fuel cell and the micro-turbine. General Electric had built two huge facilities in Hannon, New York, in alliance with a group of existing power companies and in a joint venture with the firm, "Plug Power." Allied Signal had recently completed its acquisition of Honeywell, an acquisition that held the key to achieving effective controls for both the fuel cell and the micro-turbine.

The huge, once-powerful power utility industry with its political savvy developed over decades of political interaction, found itself on a “burning platform.” Its players were reduced essentially to feeble firms engaging in power distribution, but already facing a future of expanding distributed-power. These players faced rapid, forced change.

Convergence Two

The former power utilities found themselves with urgent need for growth-revenue -- one might say "survival-revenue." The CLECs of the telecommunications industry found themselves with an urgent need for equity partners (and rights-of-way) as they, along with the ILECs, faced the onslaught of the emerging GA.

The legacy infrastructures of the former power utilities were precisely the resources the CLECs and other independent players required to match the connectivity-to-the-home of the HFC. They found the rights-of-way of the power utilities a key to providing their rapid, low-cost deployment of optical fiber in ubiquitous fashion. They found the poles and conduits of the legacy infrastructure of the power utilities -- some already with dark fiber in the ground. They tapped the know-how of the "power people" and used their trucks readily available for rapid deployment. And they found the tutorial in-being in the form of RCN, the major stealth-player in this stage of the drama.

Before we go into the dynamics through which these players became united in providing the alternative that proved to be the winner, the "AFN-GA"; we need to introduce one more element in this history, the issue of universal access. First, a look further backward in time (not shown on map).

Universal Access

As the US emerged from the depression of the 1930's, the main productivity-enhancing element of the industrial age, electricity, was deployed to the rural areas of the country -- its farms and barns -- by the Rural Electrification Agency (REA). The REA proved to be a boon to rural America. It catalyzed the cooperatively- and often municipally-owned power companies to do what investor-owned power utilities had not chosen to do. They supplied electricity to the farms and barns of rural America.

At the end of the 1990s, with the coming of the Information Age and the ubiquity of the then-existing mass-media of communications, rural Americans recognized their potential for economic and social marginalization. They faced the potential for exclusion from the mainstream of American life. Even before their brethren in the cities, they saw the necessity to take matters into their own hands to ensure that they not be left behind by the Information Revolution. Municipally- and cooperatively-owned power utilities had already begun deploying fiber optic lines throughout their territories. Final “drops” to homes, farms, and barns were initially too costly to implement directly through fiber, but “passive-coax” was an ideal interim mechanism for the "final feet" to the final user. The use of coax permitted low cost connectivity through commodity connectors that already existed at scale.

Rural Americans are among those often cited by well meaning persons, politicians, and demagogues lamenting them as "likely to be left behind" by the Information Revolution. Yet, paradoxically-once-again, these rural players were among the first to deploy fiber: north, south, east, and west. These players exercised "Yankee ingenuity" ahead of many others. In many markets, they were among the earliest to be fiber-connected. By the turn of the century, the US Department of Agriculture (USDA) had been given the responsibility for rural economics development. It actively orchestrated these activities.

A complementary phenomenon is, and was, available to center cities. Center cities are densely populated. On a cost-per-person basis, densely populated regions are inexpensive to serve with a telecommunications infrastructure, such as the AFN. This second major group that is "a problem for universal access" thus has a cost of access well-below-average for the population-as-a-whole. Sufficient resources for members of this population group to take advantage of (even this inexpensive) access, however, still must be forthcoming from society.

RCN

RCN is a jointly-owned subsidiary of Boston Gas and Electric Power Company, and XYZ, a CLEC in the Boston area. Somehow, RCN had achieved an epiphany. A number of factors had come together to permit this organization to move forward with vision, foresight, and a secure capital base.

RCN's business model called for it to deploy its high-performance fiber optic network throughout high-density areas that constitute 6 percent of the geography of the United States. Simultaneously, this geographic area is the source of approximately 40 percent of the telecommunications revenues of the United States. In more specific terms, the RCN target market encompasses two megalopolis regions: that of the East Coast and that of the West Coast; that is, the region from Boston to Washington and that from San Francisco to San Diego. RCN's approach was to work with local power companies and contract for their legacy infrastructures to provide its high performance fiber network to within 900 feet of every potential customer in the target geographies irrespective of that customer's socio-economic status. For example, before the turn of the century, RCN had deployed, a high-performance fiber network within reach of each five homes in the Annacostia region of Washington, DC. It had deployed in the Boston area, in direct competition with local HFC suppliers as well as Bell Atlantic (RCN was also engaged in rabid litigation with Bell Atlantic, right from the start).

Again, before the turn of the century, a major insightful investor, Paul Allen, the world's second wealthiest person, bought 27 percent of the equity of RCN, while accepting only 15 percent of its voting power for his investment of $1.65 billion. The significance of this investment? It was sufficient to guarantee the full build-out of the high performance fiber network of RCN in its chosen geographic regions.

Other Players

Other independent players: Qwest; Global Crossing; SpectraDyne Services (an alliance of Sierra Pacific Power Company; Hewlett-Packard; Oracle; and TelecommUnity, a fiber network firm); PSInet; Telergy; and a number of others understood the promise of optical fiber. But they needed their own "AFN-GA," the obvious response to the existing GA.

Qwest was an early player that deployed fiber in a close-to-ubiquitous fashion throughout the major corridors of commerce of the United States. It had begun the process of providing services over this network, emerging as the fourth largest US supplier of long distance services.

They, as do SpectraDyne and others, create "hosting-centers" to supply secure-services to network servers of many independent firms. SpectraDyne's entry approach to the home-market was to price its true all-fiber, initial 10Mbs offering at $13.95/mo.

Global Crossing, a worldwide player in the fiber transport market, had demonstrated its business model through deploying multiple undersea-cables; the purchase of Frontier Telecom, the fifth largest US long distance carrier, as well as a nationwide provider of cellular phone service; and a supplier of fiber connectivity to many small- and medium-size businesses and communities. Global also acquired major European suppliers of fiber to the main cities of Europe. PSInet has emerged as a major global supplier of fiber and ISP services, mainly to small- and medium-sized businesses and other organizations. It also provides multiple hosting centers for hardware server-farms.

RCN provided the example and the early success in deploying the AFN throughout its chosen geography. At first it used passive coax connectivity over the "final feet" from its network to the end users, and eventually -- after the drop in cost and the improvements in technology -- through all-fiber to the end users.

The other players together with the owners of the legacy infrastructures of the power industry, quickly moved to follow suit. The speed with which high performance fiber-to-the-curb swept across the country was breath-taking. As suggested above, the success of their approach was assured by the pricing strategies of the ILECs and the GA players.

Some Dynamics

Clearly, the ILECs had the resources (physical, intellectual, and financial) to match the deployment of RCN and its follow-on de facto allies. But the focus of the ILECs was on the protection of their pre-existing revenues (and on the obvious cannibalization of those revenues, should they attempt to match the upstart-players). Also, their early attempts to conserve their legacy copper-connectivity with its ease and low cost of deployment to the 40 percent of users within range of their "DSL-lite," 1.5 Mbps, permitted them to persist in their defensive strategies for a period of 1 to 3 years before the magnitude of even the HFC-onslaught was recognized. Their defensive strategies and their anachronistic pricing approaches facilitated the rapid deployment of the HFC as the foundation of the GA. Many experts had suggested that the low capital cost for the ILECs to deploy DSL would represent an insurmountable barrier-to-entry for AFN suppliers into the ILECs regional markets. Such advice had provided comfort to DSL suppliers. Unfortunately our history shows that it was wildly wide of the mark; AFN suppliers joined HFC suppliers in establishing this negative. Paradoxically, the pricing strategies both for connectivity and for content by members of the GA virtually assured the rapid deployment and the early financial success of the multiple players entering the marketplace with their AFNs!

Assured Interoperability

RCN had led the way in demanding and assuring the interconnectivity and interoperability of the deployers of the AFN. With its early penetration of the high-revenue regions of the country and its recognition of the need of content-providers for ubiquitous access throughout the United States, RCN with the aid of Professional Societies, has been successful in establishing an independent agency (lower-right) committed to unbiased connectivity and interoperability standards. As an enforcement mechanism, RCN has refused to interconnect with other AFN suppliers unless those suppliers committed to use of the interface standards that had been established.

Once it was clear that the RCN strategy was likely to provide reasonable ubiquity, their network plus the networks that interfaced with them were sought-after as conduit- suppliers for all of the content-suppliers that had been left-out, or priced-out, of the GA, and thus were threatened with extinction.

The AFN was technologically superior to GA's HFC. The All Fiber Network suppliers found it possible to offer content suppliers prices for access to AFN facilities well-below fees demanded by the GA, but well-above their own marginal costs. This was possible because the

GA had read its own trade paper reports and listened too long to the clucking from Wall Street. It had failed to look over its shoulder to observe the rapid emergence of the AFN suppliers. It had priced its conduit services to users at levels that reflected what the GA perceived to be its position of market power. Similarly, the content providers to the GA felt extremely secure in their strategy in only providing complementary content plus their studious avoidance of competing with each other. They, too, priced their content as would an organization with market power.

To non-GA content-suppliers, the tightly-interconnected AFNs represented an ubiquitous conduit with common interfaces for content. As just noted, non-GA content-suppliers had been "left out" of the GA and faced extinction. They then found the AFN with prices offered to the end users that were well below those from the GA. The GA's pricing policies allowed the AFN firms an excellent opportunity to under-price the GA -- while still making a handsome profit for themselves.

The rush of independent content-suppliers to take advantage of the AFN network assured end users of competitive pricing of content over the AFN. In turn, this implied lower prices for equivalent content as compared to the GA. The opportunity-cost of market-power-pricing by members of the GA made it possible for the content suppliers over the AFN, themselves, to charge end users of their services, prices significantly above their marginal cost, but more-significantly, well below the price to the user through the GA.

The Collapse

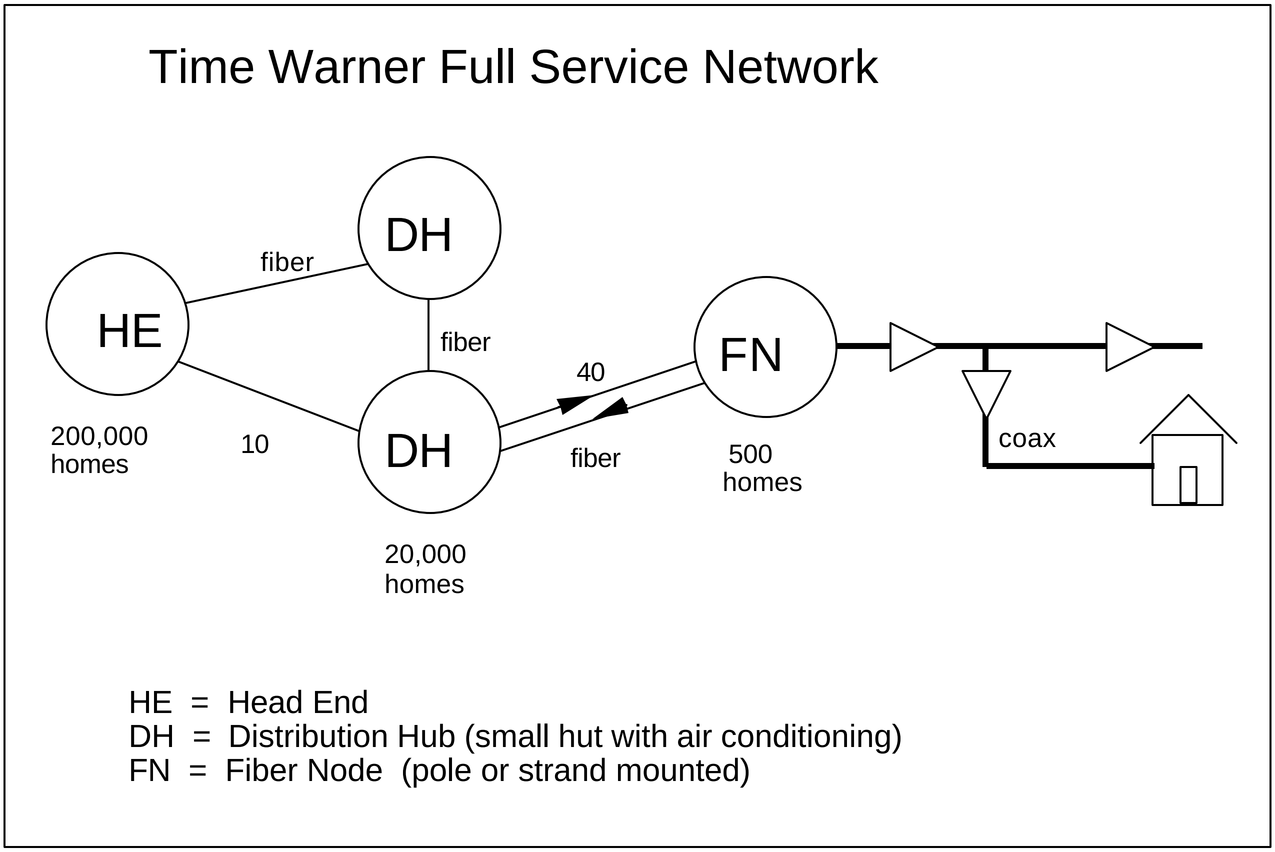
It was not long before the content suppliers who had participated in the GA began to break away. They, too, sought to reach end users at lower prices for conduit than was implicit in the pricing of the GA. They faced real competition as they offered their content over the AFN. With access to increasing breadth of content available through the AFN, and competitive pricing of the content as the result of competition over the AFN, end users also rapidly began to switch to the AFN.

This led to a collapse of the GA. It led to rapid price-cutting on the part of the HFC suppliers to the former GA and to the ultimate transition from the enormous inefficiencies of the legacy infrastructure of the telecommunications firms of the past, ILEC and CLEC alike. It led to the ubiquitous deployment of the AFN, complemented and supported by the wireless services and CWM, ubiquitous mobility through personal control elements, for which end user -- "never left home with out 'em."

Convergence Three

Players throughout the world had recognized the potential of the All Fiber Network. Inquiries poured in to consulting firms and independent consultants on strategies similar to those enunciated above for the AFN firms. As early as the turn-of-the century, the pattern for the new, global telecommunications infrastructure could be gleaned. By 2010 it had become a reality!

Appendix: Figure 2, Schematic of Time Warner's Early HFC Network Configuration



Time Warner Full Service Network- Spectrum