Bandwidth Planning and Architecture

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Here is an overview of my work with bandwidth planning and architecture. While I know that except for the FTTH stuff, there really is nothing "new" here, you may find a different twist or viewpoint in some of these items. I have broken it into three parts,

- Part One: Bandwidth Planning, a traditional HFC network
- Part Two: Fiber Architecture, comparison of different architectures
- Part Three: Fiber To The Home, my most recent experiences

My goal here is to provide you with a simple overview of the emerging network architecture issues.

Part One: Bandwidth Planning

Eight years ago with Times Mirror is when I really got serious with actually bringing Marketing into the bandwidth plan. It all seems simple now but it was revolutionary then. *(Please ignore the following numbers as they are used to illustrate the Planning Process.)*

For this exercise, I am using a conventional HFC, Ring-Star-Active network and I am assuming that this 450 MHz HFC network exists. *(Fiber architecture comes later)* Therefore, we start with the bandwidth requirements at the home or customers location. In short, engineering would put together the bandwidth elements in an a-la-cart menu format.

(A good example of this is the HITS or AT&T's DMC"PODS". HITS places a few "good" channels with several "poor" channels on each POD to encourage customers to buy more. Marketing must mix and match these to get the best content for the best price. Because Marketing does not realize they are actually engineering bandwidth, it goes pretty well.)

In the simplest form it looks something like this,

Services	MHz	450 MHz	550 MHz	750 MHz	870 MHz
Analog	500	282	288	400	450
Digital	200	48	132	144	200
NVOD	48	48	48	48	48
VOD	48	0	0	48	48
HDTV	24	24	24	24	24
Data	24	12	12	24	24
Voice	24	12	12	24	24
Service A	6	0	6	6	6
Service B	6	0	0	6	6
Service C	6	0	0	0	0
Service D	6	0	0	0	0
Future	48	6	10	12	12
Controls	12	12	12	12	12
Required	12	12	12	12	12
Total	964	450	550	750	866

Or translated into marketing lingo, it might look like this,

Services		110 CHs	192 CHs	231 CHs	300 CHs
Analog Channels	80	47	48	67	75
Digital Channels	200	48	132	144	200
NVOD Channels	8	8	8	8	8
VOD Channels	8	0	0	8	8
HDTV Channels	4	4	4	4	4
Internet Speed	High	Low	Low	High	High
Voice Lines	4	2	2	4	4
Interactive	Yes	No	Yes	Yes	Yes

There are numerous technical issues, which I have glossed over here. Things like the return bandwidth, do we use channel 2 or not, all digital set top solutions and so on. But the basic idea is that now Marketing has an acceptable Services package to work with. In fact, there are now four main Services packages (and probably numerous subsets),

1) 110 Channel 450 MHz
2) 192 Channel 550 MHz
3) 231 Channel 750 MHz
4) 300 Channel 870 MHz

Knowing what services fit into what bandwidth "pipe" is just the beginning. "What will it cost?" is missing.

BANDWIDTH PLANNING: NETWORK COSTS

In the Bandwidth Planning process, it is too early to calculate the actual costs and I am more interested in the relationship of the costs than the actual dollars right now. In other words, I am interested in seeing the incremental cost increase from one network capacity to the next higher network capacity. I want to know that going from package #2 with 192 channels to package #3 with 231 channels will increase the cost by X%. Remember, we are still trying to decide what to do with all of this and until the coast factor is known we cannot make any decisions.

All of this is further compounded by the variations of upgrade or rebuild tasks AND whatever new Network architecture changes necessary for this bandwidth to be supported thought back the entire network.

Different density will yield different costs per passing (urban, suburban and rural). This is very important when deciding on the architecture. Too often I have seen a "one shoe fits all" approach that ends up spending millions on networks, which will often be underutilized.

So lets look at the upgrade costs. *(Again, please ignore the numbers)*

UPGRADE	Cost Per Mile	Passing per Mile	Cost Per Passing
1) 110 Channel 450 MHz	existing	110	existing
2) 192 Channel 550 MHz	$4,000	110	$36
3) 231 Channel 750 MHz	$7,500	110	$68
4) 300 Channel 870 MHz	$9,000	110	$82

And the rebuild costs

REBUILD	Cost Per Mile	Passing per Mile	Cost Per Passing
1) 110 Channel 450 MHz	existing	110	existing
2) 192 Channel 550 MHz	$12,000	110	$109
3) 231 Channel 750 MHz	$18,000	110	$164
4) 300 Channel 870 MHz	$21,000	110	$191

We end up with something like this,

	UPGRADE	REBUILD
1) 110 Channel 450 MHz	existing	existing
2) 192 Channel 550 MHz	$36	$109
3) 231 Channel 750 MHz	$68	$164
4) 300 Channel 870 MHz	$82	$191

Now we have some costs that will help make us to make some hard decisions. Marketing has been busy calculating revenue on all four of the different services packages and now with the per-passing cost, they are ready to commit to some real service packages.

BANDWIDTH PLANNING: URBAN, SUBURBAN AND RURAL

Three different densities and three different costs are associated with urban, suburban and rural systems. Most likely all three types exists in one business unit or system and again most likely, all three will be very different markets. Different markets have different services or bandwidth requirements. Only after Marketing has determined what services are needed in what areas a real Network cost analysis can take place. The earlier relationship costs can help make the services decision but on a real system-by-system basis, the local density and Marketing must decide what services go where.

BANDWIDTH PLANNING: THE PROCESS

So there are not too many new surprises in the last 8 years on HFC. These basic steps of the process hold true,

1) Identify the available services and bandwidth requirements
2) Assemble Bandwidth specific Services Packages
3) Calculate upgrade or rebuild costs as they relate to additional bandwidth
4) Identify specific market needs (Service Packages) within a geographic system or business unit
5) Perform a final cost analysis based upon real costs and conditions in the specific market

The real driver behind Networks today seem to be from Marketing's desire to have more and more variety and faster services. This is where we start looking at fiber architecture beyond the traditional HFC Ring-Star-Active configuration.

PART TWO: FIBER ARCHITECTURE

I am going to cheat a little here and use an architecture analysis I did two years ago when I was with one of the over-builders. I have attached the summary sheets to the end of this paper for your review.

Faster, faster and faster and more variety seems to be what everyone wants. Existing Operators want to protect their markets, competition want to bust into those same markets and of course, the customer always wants more and bigger. This competition is not only the much-publicized "Over-Builders" but also the more well informed REITS (MDU folks) and quietly, the Power Companies.

So once I have a Ring-Star-Active HFC 870 MHz network, why do I need anything else? Well other than making the vendors happy, there is a host of reasons,

- Commercial customers served by this network want better reliability for their data and a bigger pipe
- 911 and that pesky .9999 reliability
- Everybody wants faster Internet Access
- DWDM may or may not be a great approach

And some not so easily defined but just as important to the success of the project reasons,

- The financial community or Wall Street wants to see some "flash" or uniqueness in the Architecture
- Franchise requirements
- Forward thinking migration strategies

My experience tells me to try to get everyone interested in the Network Architecture to make a commitment prior to the start of Engineering. While this seems like a virtually impossible task, starting the Engineering without a clear understanding of the "drivers" behind the network will add months to the process. It will add months as you engineer one solution after another and must repeatedly return to the drawing board to start again. The business group cannot make a firm decision until there is a firm outline of the proposed networks capabilities and the price tag. Otherwise, it is like trying on clothes until you find something that you like and the price happens to be in your budget.

So back to the Network Evaluation I mentioned earlier. In this instance, I started with the traditional Ring-Star-Active HFC and incrementally added capacity/reliability in each improved fiber architecture. The fiber to the home (FTTH) model is missing from this as it in a different class and I will get to that in Part Three of this paper.

This analysis is based upon dozens of schedules. Typical "Magic Mile" assumptions, material costs, regional labor costs, hundreds of miles of walkout information and so on. Here is a summary of the attached paper.

MODEL 1	MODEL2	MODEL 3	MODEL 4	MODEL 5	MODEL6
HFC Standard Cable TV Model RING-STAR-Active	**HFC 100 Homes RING-STAR-Passive**	**HFC 75 Homes 1550nm No DWDM RING-RING-STAR/Passive**	**HFC 75 Homes 1550nm DWDM Return Only RING-RING-STAR-Passive**	**DA HFC 225 Homes DWDM RING-RING-RING-Active**	**FTTC 24 Homes RING-RING-STAR-Passive**
FEATURES	**FEATURES**	**FEATURES**	**FEATURES**	**FEATURES**	**FEATURES**
50-870 MHz Video 5-42 MHz Return	50-870 MHz Video 5-65 MHz Return	50-870 MHz Video 5-65 MHz Return	50-870 MHz Video 5-65 MHz Return	50-870 MHz Video 5-65 MHz Return Digital	50-870 MHz Video 5-65 MHz Return Digital
Narrowcast to 50,000	Narrowcast to 50,000	Narrowcast to 50,000	Narrowcast to 900	Narrowcast to 450 (225)	Narrowcast to 1440
Cable Modem	Cable Modem	Cable Modem	Cable Modem	Cable Modem	Cable Modem or 10baseT
Cable Phone	Cable Phone	Cable Phone	Cable Phone	Cable Phone	POTS
SONET @ HUB Level	SONET @ HUB Level	SONET @ MiniHUB Level	SONET @ MiniHUB Level	SONET @ NODE Ring Level	SONET @ MiniHUB Level
12,500 MAX Exposure	12,500 MAX Exposure	900 MAX Exposure	900 MAX Exposure	2700 MAX Exposure	1440 MAX Exposure
High Maintenance	Low Maintenance	Low Maintenance	Low Maintenance	Medium Maintenance	Low Maintenance
Scaleable to 125 homes	Scaleable to 50 homes	Scaleable to 38 homes	Scaleable to 38 homes	Scaleable to 115 homes	No Scaleability
			NORMAL Status Monitoring	NORMAL Status Monitoring	BEST Status Monitoring
$508	**$516**	**$597**	**$616**	**$654**	**$797**

These per passing costs are the real things from two years ago in Kansas City. I am sure that I could debate what costs were used, how they were included and so on but I am comfortable that these new-build numbers were very realistic then. Pretty straightforward

MODEL 1	0 Mini-HUBS	644 nodes
MODEL 2	0 Mini-HUBS	3222 nodes
MODEL 3	336 Mini-HUBS	4032 nodes
MODEL 4	336 Mini-HUBS	4032 nodes
MODEL 5	112 Hubs	1432 nodes
MODEL 6	180 HDT	20125 ONU

until you take a closer look at some of the components and the geography. For example,

While these cost models have accounted for the location expense (find the property, easement rights. Permits, site preparation and so on), cost vary significantly from city to city. An architecture that cost $597 per passing in a mid-West city may be over $900 per passing in the northeast metro areas. My point is that “One shoe does not fit all”.

Here is a simple network drawing I made 2 years ago of Model 5 above,

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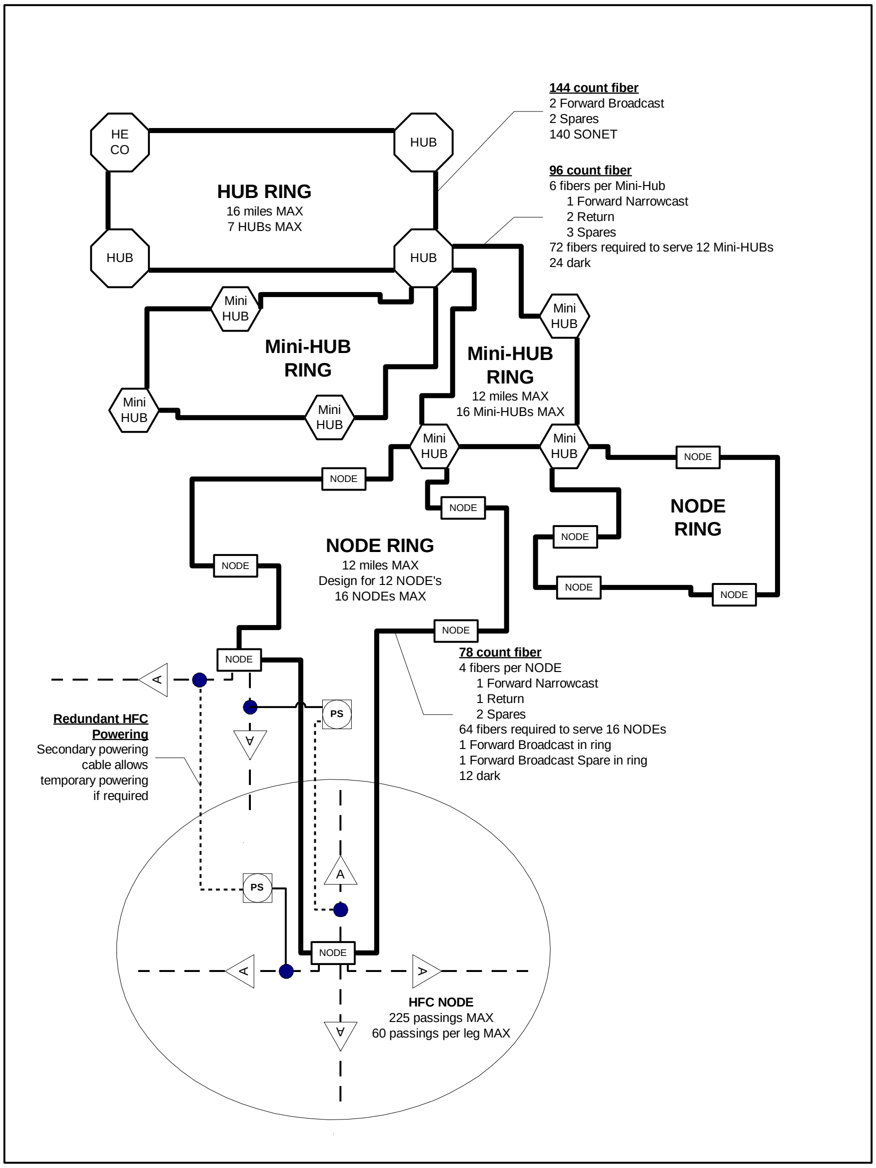
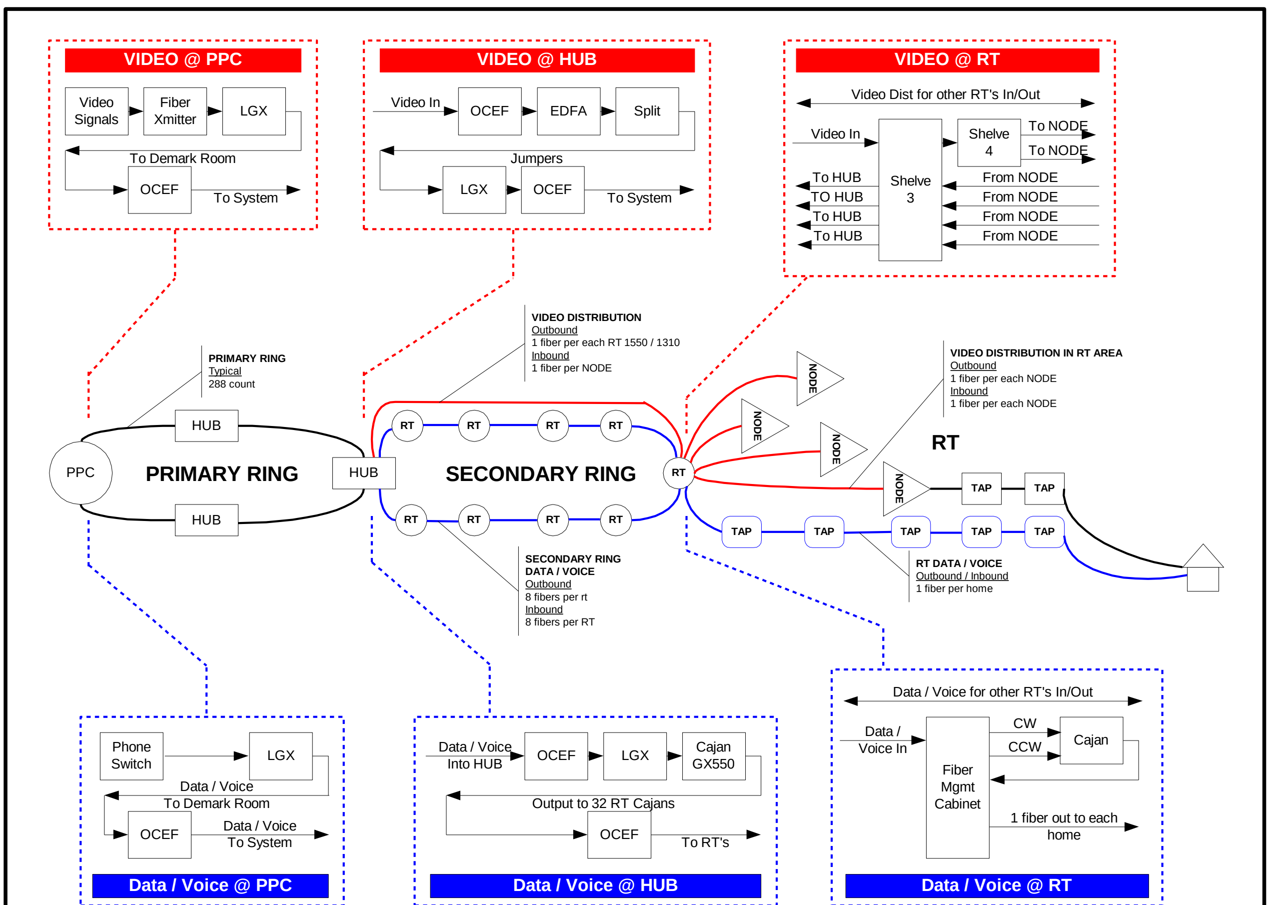


(Note the Redundant HFC Powering showing one power supply supporting two nodes)

There is no quick and simple "Magic Mile" way to perform a valid cost analysis. Architectures can be compared, just as air conditioning systems in a house can be compared. Nevertheless, the truly efficient and elegant network architecture must be treated like building a custom home. The nature of the land it sits on must be incorporated into the design. The owner's wishes must be there. All of the building codes and ordinances must be observed. My point in this Part Two is that while many people can compare architectures, only experienced people can fit the right architecture to the right market and network demands.

PART THREE: FIBER TO THE HOME



Network Block Diagram Prepared by: Frank Gates 1-16-2002

I created this Network diagram as both a training aid and a tool to bridge the conflicts between Inside and Outside plant personnel. The training because everyone was very confused about Secondary rings and the conflicts centered on who does what and takes responsibility during construction and activation.

Let me explain this particular FTTH approach. All services (voice, video and data) are transported via Primary or Metro Ring to local HUBS. At this point, the video is separated from the voice and data and becomes (essentially) a conventional HFC Network. As the video fiber travels outbound to the customer, it passes through the RT (Remote Terminal, see the insert) location only as construction efficiency and continues to the NODE. This leads me into the migration strategy.

FTTH: MIGRATION STRATEGY

As this technology in a practical application is literally being invented as it is constructed, engineering decided to build this co-located HFC video distribution network along with the FTTH Network. The migration strategy is that when the market has produced an acceptable voice-video-data platform, the HFC network will be abandoned and video will be integrated into the FTTH Network.

As far as the FTTH Migration Strategy, the really is no strategy. The capacity should satisfy all future needs. Now, this is debatable but this is the engineering philosophy behind the Network, which I have been working on for the last year.

FTTH: RT (REMOTE TERMINAL) AND NODE LOCATIONS

The RT cabinet is comparable in size to the Marconi MESA series and requires concrete pad placement, powering and various permits. It is highly objectionable to the residents nearby the chosen locations. As a result, RT placement is a big issue.

The NODE on the other hand is a conventional outdoor CATV type enclosure and offers much more flexibility.

Both of these location issues can be overcome but they are part of a bigger consequence or Distribution Architecture problem.

FTTH: DISTRIBUTION ARCHITECTURE

In a conventional HFC design, the designer would follow some sort of checklist and locate the NODE. Once the NODE is located, the following RF design is very traditional and follows appropriate strand and easement routes throughout the Node Area.

Likewise, the Fiber Video and Data design is standard between the HUB and the RT location. After that, there is no traditional design to get a single fiber to every passing in the RT Area. Alternatively, is that the NODE Area? This is where things start to become fun.

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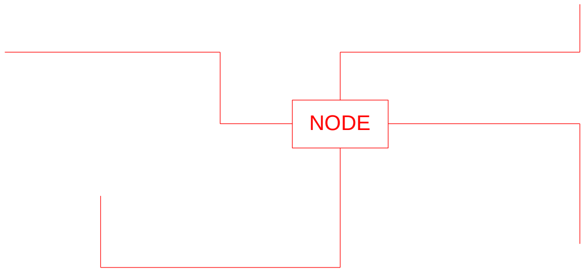
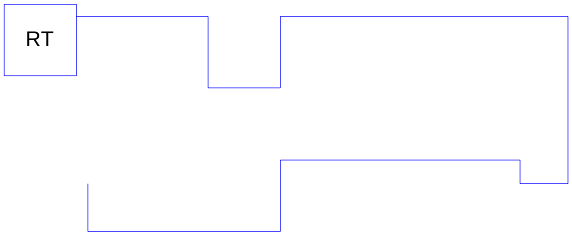
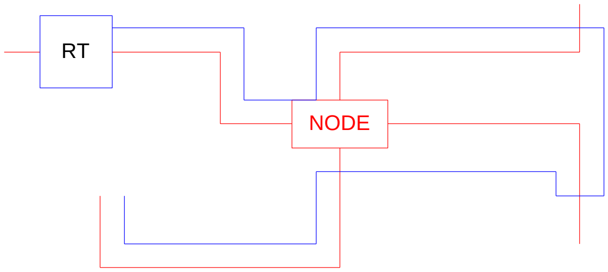


Here is a simple HFC NODE with four distribution legs. Everything is pretty traditional, no surprises.



Here is the same geography with the RT and Distribution fiber outbound to each of the passings, again no surprises.



Moreover, here are the two together and the world gets a little more complicated. It becomes complicated in terms of Network Maintenance. Given the above Distribution model, different homes can experience different voice-video-and data service problems depending on where they "sit" in the network. Services arrive and depart in the same direction, opposite directions and so on.

In construction cost efficiencies, the designer will try to co-locate everything possible, especially in underground routes to minimize costs. This is a good thing. However, in the real world, the RF designer and the fiber designer do not seem to be aware of what each other is doing. End result is efficient RF design plus efficient fiber design equals very expensive and poorly design Networks.

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A second issue in the Distribution portion of the plant is the actual RT placement location itself. The folks who are obtaining the RT location are trying to get locations, which will have the lease outcry from the neighboring homes. Typically, industrial sites, public easement on highways and other low population sites are selected. Then 60 to 90 days later, the designers start laying the fiber and the coax on the RT or NODE Area (did we ever decided which was which?) and the RT site loses its appeal.

These same RT sites, which are away from the homes and less objectionable to the homeowners, now must move traditional coax to every tap and a single fiber to every passing. With only an in and an out route to the RT location, it is not unusual to have conduit packages (co-located ducts) of 6, 8 or sometimes 12 2" conduits in the same route. This is a HUGE problem.

Easy fix, move the RT into the middle of the neighborhood, you do have easement rights after all, don't you? No good, not when time to market is pressing and public opinion is a key element of the Marketing plan.

So what do you do? Well, easy, you hire an experience person like me to show you the ropes. Seriously, the solution is to get design moths out ahead of construction with a clear understand of this problem in hand during the RT selection and subsequent design process. Some of the solutions are not very pretty but they are doable with the right planning and knowledge.

FTTH: PROVISIONING

With VoIP, end to end, customer to switch or cloud, connectivity, automated provisioning becomes a reality. Unless the initial walkout information did not gather, the very specific and correct address information. Traditional walkout is concerned with house counts and signal requirements in the distribution network.

A transposed street number or misspelled street name can always be corrected later without a lot of heartburn. Well, this is not true when the installer is standing in the customer's living room and the voice service cannot be recognized by the switch. This is now a big problem.

Fixable? Yes. Preventable? Yes and that gets back to experience and knowing what information is critical to the process.

FTTH: FIBER TAP SPLICING

What is a fiber tap and who is doing the splicing. The real issue here is do you pay for the splicing during construction for 100% of the passings or during Installation on a success based percentage of the passings.

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There are two sides to this issue and the answer lies somewhere between the need to get the services into the market and the skill levels required in the installation department. I am point this out as it was a surprise to me and I suspect it will catch a lot of folks off guard in the future.

CONCLUSION

I have outlined my general bandwidth planning and architecture experience here. I hope I have provided you with the material you were looking for.