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Fiber Networks for Telephony and CATV

Lynn D. Hutcheson
Howard L. Lemberg
Chairs/Editors

5–6 September 1991
Boston, Massachusetts

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FIBER NETWORKS FOR TELEPHONY AND CATV

Volume 1578

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FIBER NETWORKS FOR TELEPHONY AND CATV

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SESSION 1

Power, Maintenance, and Testing

Chair
John Smoak
BellSouth Services

Centralized power architectures and costs

Mark O. Vogel

Linda F. Garbanati

Ameritech Services, Rolling Meadows, IL 60008

ABSTRACT

Currently, most Regional Bell Operating Companies (RBOCs) favor centralized powering as the predominant method for powering Fiber-In-The-Loop (FITL) systems. This is because centralized power systems can provide indefinite power backup, as well as consolidation of power equipment and batteries. The capabilities of such a power system are dependent on several parameters including supply cable gauge, load requirements, and equipment location. This paper will examine two centralized powering architectures and determine the impact of these parameters on the installed first cost of the power system. The paper will also provide a review of the anticipated narrowband FITL power requirements and specifications.

1. INTRODUCTION

With a Fiber-To-The-Curb (FTTC) system, fiber is brought from headend electronics, located in either the Central Office (CO) or Remote Node (RN), to an Optical Network Unit (ONU) where the fiber is terminated. Metallic service cables, running from the ONU to the residence, then connect several customers to the ONU. Because there is no longer a direct metallic connection from the CO or RN to the customer with FITL, an alternative method must be used to provide power to the telephone and to the ONU electronics. Two methods for providing this power have arisen, each of which yield inherently different benefits. "Local" power utilizes ac power at either the residence or a near by utility power cable, an ac/dc conversion at the power source, and a short metallic cable (~650 or less) to carry power to the ONU. Batteries placed at each ONU provide backup power in the event of the loss of ac power. This architecture has the advantage of minimizing or eliminating the placement of metallic cable in the distribution plant, and in most cases has a lower installed first cost (IFC). The second method, "Centralized" power, utilizes centralized power equipment and batteries which may be located at the CO, RN or in a separate power node. Long metallic cables (up to 12 KFt.) then carry the power to each ONU. The primary advantage of this architecture is that indefinite power backup can be provided through the use of backup generators at the RN or power node, or gas engines if the equipment is located in the CO. It is because of this backup capability, which can ensure continuous telephony service, and the consolidation of the power equipment and batteries that the majority of RBOCs favor this powering option for narrowband FITL applications. The focus of this paper will therefore be on centralized power architectures and the effect of

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cable gauge, ONU load, and power equipment location on their IFCs. To accomplish this, the paper will also examine FITL power requirements and specifications.

2. CENTRALIZED POWER ARCHITECTURE

2.1. Generic power architecture

In general, a centralized power system gets it power from a bulk power source which provides a dc voltage output. Since this power will need to be transported over a long distance, the dc output from the bulk source is stepped up to a higher dc level via a dc/dc conversion before being sent to the ONU. The power is then carried over metallic facilities, which will vary in gauge depending on the system parameters, to the ONU. The high dc voltage level is then stepped down by a second dc/dc conversion at the ONU, to the levels required by the ONU electronics and the customer's telephone.

Because of the inefficiencies of the power conversions and power transport, only a portion of the power originally provided by the bulk source is actually delivered to the ONU electronics. Typically, the dc/dc conversions will result in 15% and 20% losses at the headend and ONU respectively, and up to a 50% loss in the cable. With the existing tradeoff between conversion efficiency and the input voltage range capabilities of the ONU converter, however, a loop efficiency of 70% or greater is usually designed into the system. Therefore, the losses in the loop will be limited to a maximum of 30%. Loop efficiency will also be dependent on the ONU load and converter efficiency, the cable gauge, and the loop length, the latter two of which can be easily varied. This makes the loop efficiency the most flexible parameter for maximizing the overall system efficiency. Depending on the actual loop efficiency, the system at a minimum will be 48% (0.85*0.8*0.7) efficient. Thus to provide 1 W of power to the ONU electronics, a maximum of ~2.1 W are required at the output of the bulk power source.

2.2. ONU capacity and power requirements

Bellcore document, TA-NWT-000909, "Generic Requirements and Objectives for Fiber In The Loop Systems" provides the generic requirements for a FITL system, and more specifically defines the ONU traffic capacity and power consumption requirements. Considering the traffic first, the ONU is required to support a certain ringing capacity while simultaneously supporting a certain off-hook capacity as shown in Table 1. This capacity is based on a per line traffic load of 9 Centa Call Seconds (CCS), and an assumed non-traffic sensitive FITL system. For demand between the values listed, the larger of the two numbers for ringing lines, and linear interpolation for the lines off-hook should be used. Thus, an 8 line ONU (72 CCS) for example, would be required to support a peak capacity of 3 lines ringing and 5 lines off-hook.

Load Capacity (CCS)	Ringing Lines	Lines Off-Hook
≤60	2	9
400	3	20
700	4	30
1000	5	40

Table 1 - FITL system simultaneous ringing and off-hook capacity requirements.

Along with the traffic requirements, TA-909 also specifies the power drain per line at the ONU. These two specifications together will determine the peak load requirements of the ONU. As can be calculated from Table 2, and the traffic requirements of Table 1, the peak load for an 8 line ONU would be about 10.9 W.

Item	ONU Power Consumption (W)
Idle (no services equipped)	1.80
Additional per line equipped	0.18
Additional per line off-hook	0.72
Additional per line ringing	1.35

Table 2 - ONU equipment power consumption.

For the centralized power system, TA-909 also specifies the system line voltage requirements. Because the loops for this powering option will be long, the specification calls for a line voltage of -130 Vdc. This voltage falls into the Bell Operating Company's Class A3 specification which limits the power on any line to 100 W, and the current to about 0.75 A.

2.3. Study architectures

Based on the specifications described above, two centralized power architectures will be examined. These two architectures, shown in Figure 1, both have the same headend power equipment. The bulk power source is comprised of a primary ac source and a secondary battery source. The primary source takes commercial ac power and converts it to a voltage level of -48 Vdc. This is a common voltage in the telephony world, and since this source may also power equipment other than the ONU, the -48 Vdc level is used. In the event of commercial power unavailability, the system is switched to battery backup (also @-48 Vdc) to provide power until ac is restored or until a generator is accessed. The -48 Vdc output is then stepped up to the -130 Vdc line feed and is transported to each ONU over a dedicated metallic cable with the star architecture, and a shared metallic cable with the bus architecture. Since each feed is limited to the 100 W specification, the bus architecture will require a significantly lower loss cable than the star, to enable more than a few ONUs to share the bus feed (the exact number of ONUs will be detailed in section 2.4). At each ONU, a second dc/dc converter converts the power back to the -48 Vdc level as well as any other dc level required by the ONU electronics. For the paper, an 8 ONU will be used.

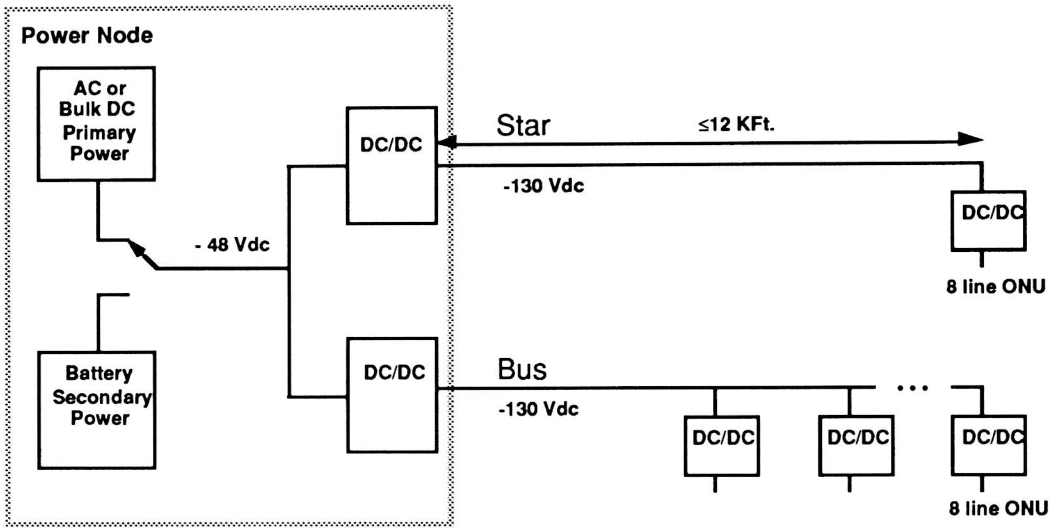

Figure 1 - Star and Bus Centralized power architectures.

2.4. Cable capacity

The load at the ONU and the distance from the power node to the ONU will determine which cable gauge can be used in the power system. Looking first at the serving distance, each ONU will range from a minimum of several feet from the power equipment, to a maximum of 12 KFt. (Carrier Serving Area distance limit). This maximum distance is flexible, however, and can be controlled by the placement of the power equipment. In terms of the ONU load, each power feed must be capable of supporting the peak load at an ONU at the maximum serving distance. This load, as previously mentioned is about 11 W for the 8 line ONU powered by the star power architecture. Figure 2 shows the effect of loop length on loop efficiency for both 19 and 22 cable gauges at this load. Remembering the 70% efficiency minimum imposed by the ONU converter, the 8 line ONU can only be served by 22 gauge cable within about a 7.5 KFt. range. If the maximum loop length is beyond this range, 19 gauge cable must be used.

Figure 2 also shows the efficiency curve for the bus power architecture, which is only slightly more efficient than the 8 line 19 gauge curve. Based on a 14 gauge bus cable, the 100 W feed limit is reached before the loop efficiency falls below 80%, even at a 12 KFt. loop length. Although not explicitly shown in the figure, this occurs at a total ONU load of about 65 W (@12 KFt.). To determine how many ONUs this translates into, Tables 1&2 must be used. If a single bus feed to multiple ONUs is considered to be equivalent to a single feed to one large ONU in terms of the traffic requirements, then the Table 1 and 2 specifications limit the number of 8 line ONUs on the bus to a maximum of 10 (@720 CCS & 62 W).

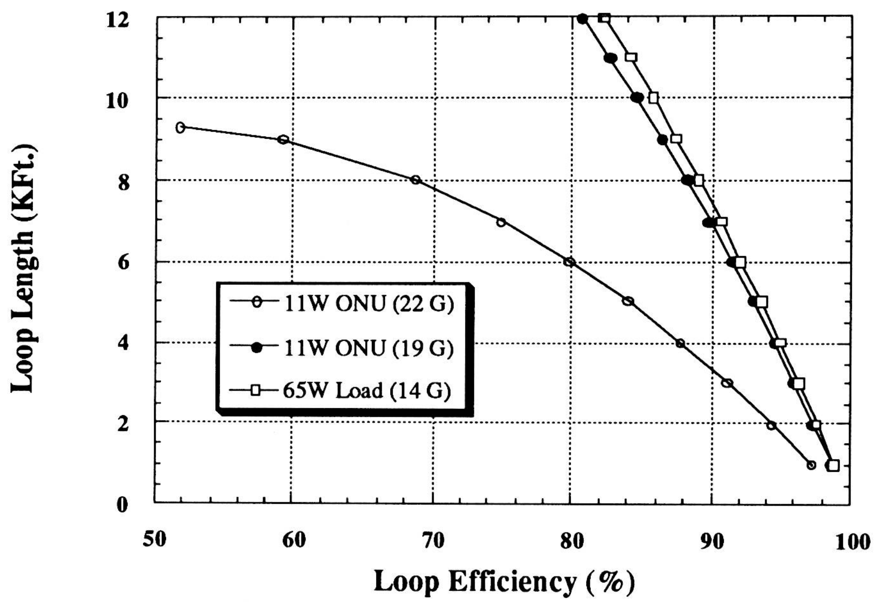

Figure 2 - Star and Bus loop length vs. loop efficiency curves.

2.5. Power source and backup battery requirements

Although the cable gauge is determined by the ONU peak load, the power source and backup battery requirements are set by the system load. For this paper a 600 line capacity, which is the maximum number of lines that can be served within a distribution area, is assumed. This capacity, however, is an ultimate capacity and is usually not achieved in actual implementations. Typically, only about 4 lines will be served per ONU on average due to the randomness of second line take and odd numbers of lots in placement. If it is assumed that 100 ONUs will be sufficient to serve the DA, the number of lines that must actually be supported is 400. Since the power system capacity (source and batteries) is not defined in TA-909, the power requirements will be interpreted from TR-TSY-000057 "Functional Criteria for Digital Loop Carrier Systems" which is the basis for much of TA-909's specifications, and TR-TSY-000406 "DC Bulk Power System for Confined Locations". For the power source, the assumption will be made that since the headend electronics of the FITL system are only required to support a certain traffic level, the power source should only support an equivalent level of traffic plus some margin. This level is taken from TR-57 which provides ringing/off-hook requirements based on the system traffic load. Taking a single reading from a more exhaustive table in TR-57, for a 400 line system (@9 CCS/line) the power node would have to minimally support 10 lines ringing and 117 lines off-hook. Using this number, and Table 2, dictates that on average the system must support a 3.5 W load per 8 line ONU.

Because of the increased call traffic during power outages, the requirements for the battery backup are more stringent than those of the power source. TR-406 specifies an 8 hour battery backup that supports all lines off-hook for the first three hours and one sixth of the lines off-hook for the remaining 5 hours. Two further specifications require the battery capacity to be measured at a loop length of one half the maximum length, and that an assumed 20% decrease in battery capacity over the battery life be included. Thus based on TR-406, the backup system must support 400 lines off-hook for the first 3 hours of backup and 67 lines off-hook for remaining five hours. Again using Table 2, this requires the battery backup, during the first three hours, to be capable of supporting a 5.4 W average load per 8 line ONU. For the remaining 5 hours, the backup must support a 3.0 W average load per ONU.

Table 3 below summarizes the power requirement for the source, the backup, and per power feed at the peak load. These values represent the power consumption of the ONU electronics only, and do not include converter losses or loop efficiencies.

			Battery Backup	
Star	Peak (W)	Average (W)	All OH (W)	1/6 OH (W)
8 Line (Star)	10.9	3.5	5.4	3.0
8 Line (Bus: 10)	61.5	35.0	54.0	30.0

Table 3 - Summary of power requirements per power feed.

To determine the final power requirements of the source and battery backup, the efficiencies of the system must be included. This is known for the converters, but is dependent on load and distance for the loop efficiency. To demonstrate the combined affect of the variation of these two parameters on loop efficiency, Figures 3A & 3B show plots of the loop length versus the ONU load for constant loop efficiency curves and cable gauges. The figures show that the efficiencies set by the peak load and maximum loop length are lower than at the average operating load (see Table 3) and an average loop length. This means that although the system is designed to have a worst case loop efficiency of 70% (star) and 80% (bus), in general it will operate in the 95% (star & bus) or higher loop efficiency range.

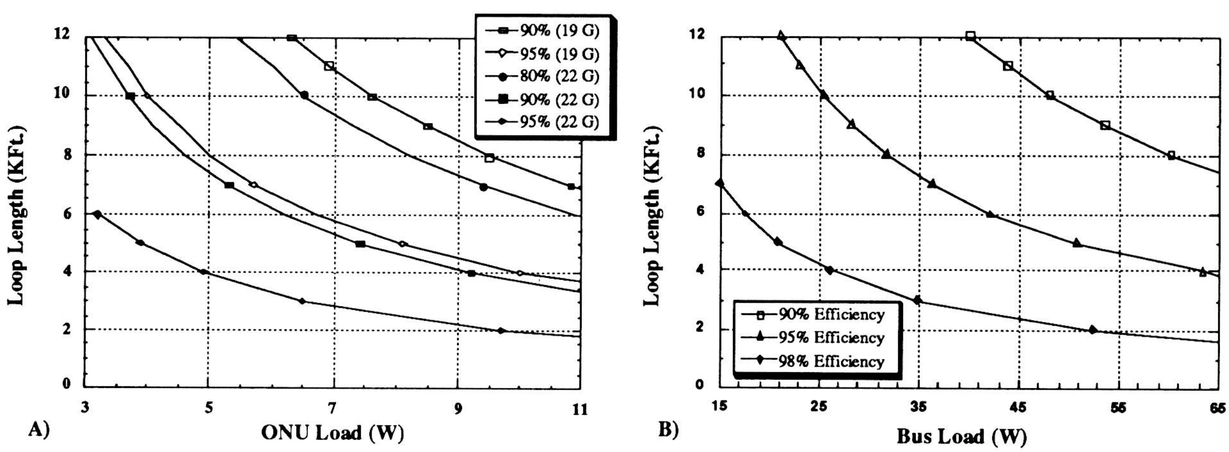

Figure 3 - Star and Bus architecture loop length and ONU load curves.

To determine the overall system requirements, the following section will look at three different implementations of the power architectures and examine the impact of the implementation on the power system cost.

3. ECONOMIC ANALYSIS

3.1. Implementation scenarios

As described in section 2.4, the maximum loop length within a Carrier Serving Area (CSA) is 12 KFt. This distance is measured from the entrance to the CSA to the customer's location. Placement of power equipment at the CSA would allow coverage of the entire CSA from a single point, but would also maximize the the quantity and lengths of the power cable placed. Moving the equipment into the entrance to a Distribution Area (DA) within the CSA would reduce the amount of cable by reducing the loop lengths, but would also increase the number of power equipment sites required. Finally, moving the power equipment to some centralized point within the DA would reduce both the cable length and the backup equipment required, while keeping the number of nodes the same as in the previous case. This type of arrangement, however, would complicate the engineering, placement, and administration of the power cable since it would run both directions in the trench instead of one direction as with the placement of equipment at the entrance to the CSA or DA. To determine the impact of the placement of the power equipment on the IFC of the bus and star architectures, the following three implementation scenarios will be examined:

1) **Power within the DA:** The power equipment is placed the center of the DA. The maximum serving distance is 6 KFt., and the average distance is 3 KFt. The equipment is sized to support a single DA (up to 400 lines). 22 gauge cable is used with the star architecture to transport power to the ONU, and 14 gauge cable is used with the bus.

2) **Power from the DA:** The power equipment is placed at the entrance to the DA. The maximum serving distance is 9 KFt., and the average distance is 4 KFt. The equipment is sized to support a single DA (up to 400 lines). 19 gauge cable is used with the star architecture to transport power to the ONU, and 14 gauge cable is used with the bus.

3) **Power from the CSA:** The power equipment is placed at the entrance to the CSA. The maximum serving distance is 12 KFt. (3 KFt. of which is subfeeder cable between the equipment and the DA), and the average distance is 6 KFt. The power equipment is placed in a CEV, and is sized to support 3 DAs (up to 1200 lines), but only the allocated cost for a single DA will be used. 19 gauge cable is used with the star architecture to transport power to the ONU, and 14 gauge cable is used with the bus.

3.2. Power equipment requirements

With the maximum and average loop lengths set, the loop efficiencies can be taken from Figures 3A and 3B for the loads found in Table 3, to determine the total power and battery backup requirements for the power equipment. As an example of this calculation, with the star architecture, an 8 line ONU has a power requirement of 3.5 W on average. On 19 gauge cable, at an average distance of 6 KFt., the loop efficiency is about 97% (from Figure 3A). This means that with dc/dc converter efficiencies of 85% and 80%, at 400 lines (100 ONUs) the supply equipment must be capable of supporting a load of about 526 W [~3.5*100/(0.85*0.8*0.96)]. A similar calculation is made for the battery backup, except that the ONU load has two values, and an additional 20% capacity for end of life must be applied. Table 4 below summarizes the results of these calculations and provides the equipment and battery backup requirements for the three implementation scenarios for both the bus and the star architecture (Table 4 will deviate slightly from actual calculations due to rounding in the tables).

Max. Length (KFt.)	6	9	12
Avg. Length (KFt.)	3	4.5	6
8 Line (Star)			
Supply (W)	526	522	500
Battery (AH@42Vdc)	142	141	142
8 Line (Bus)			
Supply (W)	525	530	508
Battery (AH@42Vdc)	141	143	146

Table 4 - Supply and battery requirements for three implementation scenarios.

It becomes clear from the table that the power requirements for the three scenarios and architectures are not significantly different based on the assumed parameters. Scenarios 1 & 2 require supply powers of about 525 W, while scenario 3 requires slightly less at 500 W. All of the scenarios, however, require a battery backup of about 140 AH. Since the source and backup equipment requirements are all similar, the difference in cost between the scenarios will therefore be directly related to the amount and gauge of the cable used.

3.3. Installed First Cost Results

To determine the the IFC for the power architectures, each of the scenarios was modelled using a generic subdivision serving approximately 400 lines. It was assumed that all of the implementations were new build, with no existing structures or facilities. The results of the analysis are presented in Figure 4, with the cost for the power cable and placement (Cable), power supply, battery backup, housing, and placement (Eqpmt), and subfeeder cable and placement (Subfeeder) costs shown separately. As the figure shows, all of the scenarios cost between $150 and $200 per line, with power within the DA being the least expensive implementation, power from the CSA the most expensive, and power from the DA in the middle. These results are not surprising since the power equipment costs are equivalent between the implementations and since the CSA scenario requires the greatest amount of cable and thus has the greatest cable cost. However, if the CSA equipment site is located closer to the entrance to several DAs (as could occur in an actual implementation), and the subfeeder cable is reduced or eliminated, then the cost of the CSA scenario is equivalent to the within the DA scenario.

Comparing the bus and star architectures, the star architecture is the least expensive implementation for scenario 1, but is more expensive for scenarios 2 & 3. This occurs because of the subdivision layout which has few branch points and long streets. It is also the result of the cable sizing of the smaller gauge cables (19 & 22), which at the smallest come in 25 pair and 50 pairs cables, whereas the 14 gauge cable comes in 1 to 10 pair cables. This results in a penalty for the star architecture as the size of the cable required goes falls between 25 and 50 as it does in scenarios 2 & 3.

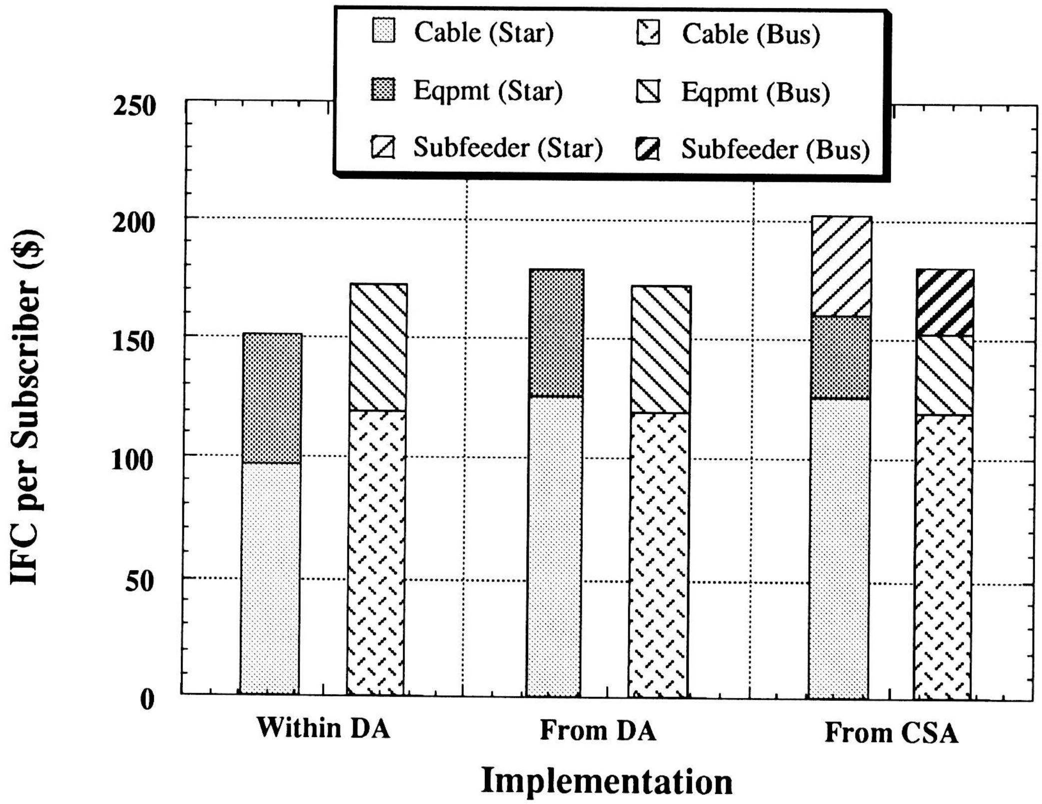

Figure 4 - IFC for three power implementation scenarios.

4. CONCLUSIONS

Several conclusions can be drawn from the analysis of the three implementation scenarios. In terms of the power equipment placement, although the within the DA scenario is the least expensive scenario in this analysis, it has the greatest potential for higher implementation costs. This would arise from implementations where there is restricted access (can't run lateral cables between street for example), and the ability to minimize cable lengths from a center feed is reduced or eliminated Also, because of the necessity to run cable in both directions in the trench, scenario 1 is not conducive to a rehabilitation implementation where the existing copper plant (fed from DA entrance) would be re-used to power the FITL equipment. Scenario 3 is the most expensive implementation, and it requires the placement of a large cabinet or CEV if space or an existing structure is not available. For these reasons, power from the DA is the recommended implementation. Although it is more expensive than power within the DA, its cost are not as dependent on the layout of the implementation as that scenario, and it is less expensive and does not require the large structures of scenario 3. However, if a CEV or a large cabinet exist and have the space available, then power from the CSA may be the best implementation. Power from the DA is also best suited for rehab, since the cross box at the DA entrance can be used to distribute power over the existing pairs.

In terms of the power architecture, the star architecture seems to fit best with near and long term needs. Even though the bus is less expensive in scenarios 2 & 3, the difference in cost is less than $10 per customer in the power from the DA scenario, and may actually be less in other locations where the layout is not as well suited to the bus architecture as the modelled subdivision. The bus architecture is also an unfamiliar architecture, and cannot be used with re-use of existing plant which utilizes a star implementation. Finally, if the bus did become the architecture of choice, only certain cable sizes would be inventoried, and the bus would then incur breakage costs like the star architecture.

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