A Digital Subscriber Carrier System for the Evolving Subscriber Loop Network

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Abstract—**Subscriber carrier systems such as DMS-1(TM) are currently being widely used for rural outside plant relief applications. However, there is a much larger application base for subscriber carrier in urban areas. Urban carrier systems will require significantly different features compared with rural systems. The applicability of these systems in urban loop plant is discussed and a system being designed by Northern Telecom and Bell-Northern Research to complement the existing DMS-1 system is described.**

BACKGROUND

ELECTRONICS in the loop plant has progressed significantly since the early 1970's in gaining widespread acceptance in the telephone operating companies. It is now recognized that loop electronics can be used as a primary provisioning tool in the outside plant environment. Over 50 percent of the growth in the rural loop plant is now being electronically derived.

The most rapidly growing type of loop electronics is the digital subscriber carrier system (Fig. 1). This system provides pair-gain by employing digital transmission on existing cable pairs to derive additional subscriber lines. The applications of such systems in North America have been well established in the rural areas for providing the basic POTS (plain old telephone service) and coin service capabilities. The main advantage of using digital carrier in rural areas is reduction of capital costs of provisioning loops and deferring capital expenditures until actual demand occurs. At greater than 20-30 kft from the central office (CO), the available digital carrier systems generally prove more economical than installing a new cable. Another advantage is the improved transmission grade of service inherent in the digital systems. Most rural applications also involve some sort of rural service upgrade to single, 2-, or 4-party service. This upgrade, together with the transmission improvement from digital carrier, has substantially improved the service provided to the rural subscribers.

Subscriber carrier applications in urban areas have, to date, been very limited. However, as digital technology continues to advance, it will make possible digital carrier systems at a cost substantially lower than present day systems. Such systems will thus begin to penetrate into urban plant. A previous paper [1] on digital loop carrier stated that in a few years, digital carrier will provide close to 25 percent of the total Bell System growth.

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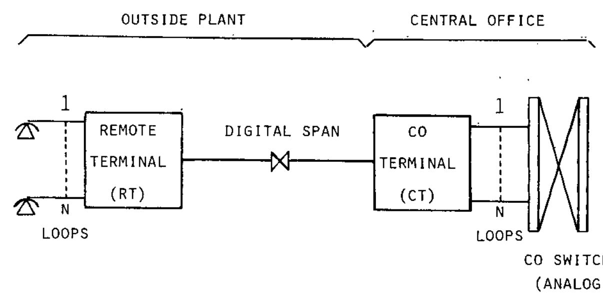

Fig. 1. Digital subscriber carrier system.

CONCERNS WITH THE URBAN CABLE PROVISIONING

The majority of service provisioned today in the urban plant is on cable. The main reason is that of cost. Most loops in urban areas are short, installed as large-sized cables and utilize fine gauge wires. Thus, loop costs are considerably lower compared to those in rural plant, e.g., the ratio of the cost per pair of a 900 pair 26 AWG cable (common in urban plant) and a 100 pair 22 AWG cable (common in rural plant) is almost 1/3. However, installed copper costs will continue to rise relative to the newer carrier systems which, through plug-in deferrals, will also allow the much-needed capital containment in these times of tight budget constraints. Thus, carrier will begin to be considered as an alternative to cable. There are also other concerns with urban cable provisioning that will encourage carrier in urban areas. These are as follows:

1) underground duct congestion

2) susceptibility to changes in growth forecasts with cable provisioning

3) special service provisioning over existing loop plant.

Underground Duct Congestion

Most urban cables are placed in underground duct structures. Because of the practice of assigning a pair per subscriber and of the heavy demand for circuits in urban areas, there is a sizable duct congestion and manhole crowding problem [2]. Reinforcing underground structures in urban areas can be very expensive. To reinforce feeder route structures can cost up to around $50 000 per kilofoot.

Susceptibility with Forecast Changes

Forecasting network capacity to actual demand along a feeder cable route is difficult and permits little flexibility once the investment is made. Many factors such as changes in economy, population shifts, etc., work against the planners. To provide flexibility for uncertain growth situations, the plant is often designed with excess capacity. If the growth

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does not materialize, the telco is faced with unnecessary investment in idle plant. If unexpected growth occurs, there are problems of long lead times to install additional cable facilities.

Special Service Provisioning

The cable loop plant is designed to meet the transmission and signaling requirements for POTS. Unfortunately, most special services have to be designed to much tighter specifications than POTS, e.g., a PBX-CO trunk is often designed for a maximum of 3-5 dB loss while the cable plant is designed for the maximum 8 dB loss for POTS. Thus, loop electronic treatment (VF and/or signaling repeaters) is required at the CO to compensate for the inadequacy of the existing cable plant.

The situation can be worse in the case of digital data circuits for which line conditioning is required (e.g., remove load-coils, bridged-taps, correct split-pairs, etc.) to ensure suitability of the physical pair.

Besides the expense of making the existing cable plant suitable, the process involves long lead times to provide the service, e.g., it may take several weeks to provide the loop access to a digital data service.

In addition, the volatile nature of the business segment must be considered. The average lifetime of the special service circuit is only 2 years. Often, the telcos are unable to recover their investment within the lifetime of the circuit when the circuit is provisioned over a physical pair.

BENEFITS OF LOOP CARRIER IN URBAN APPLICATIONS

The above concerns with cable provisioning can all be successfully addressed through digital loop carrier systems. While initial considerations of an urban carrier system may indicate traditional cable provisioning is equally attractive from an investment viewpoint, the secondary financial considerations at a time of high inflation are significant. These secondary benefits include the following:

- maximizing capability of depreciated underground plant through pair-gain, especially where duct congestion occurs
- capital containment through plug-in deferrals
- reduced engineering and operational costs especially for special services
- enhanced prove-in of future digital switch.

Duct Congestion

The use of subscriber carrier can alleviate the structure congestion problems by using existing cables to derive additional circuits through pair-gain. As an example, if the duct reinforcement of a 3 kft feeder route section is avoided or deferred through the use of subscriber carrier, the following typical PWAC savings could be realized:

1) $150 000 PWAC for avoiding reinforcement

2) $50 000 PWAC for deferring reinforcements by 5 years.

Such savings would considerably enhance the proving-in of digital carrier.

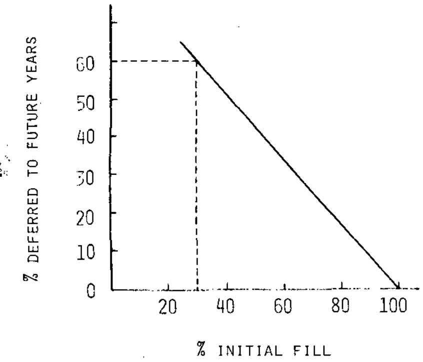

Fig. 2. Capital deferral through modular urban carrier system.

Capital Containment

Traditionally, cable is installed for 5-10 years growth. Thus, capital investment has to be sunk from day 1. On the other hand, digital carrier systems with their deferrable plug-in capability can spread the capital investments over the 5-10 year period as required. Fig. 2 indicates the percentage of capital that can typically be deferred to future years as a function of the initial fill in a 500 line system. At a 30 percent initial fill, about 60 percent of the capital investment can be deferred into the future years.

The capability to add capacity as required enables digital carrier systems to provide an outside plant facility that is less susceptible to forecast changes. Thus, investment in idle plant can be minimized, capital containment programs implemented, and in cases of unexpected growth, faster relief can be provided at a minimum cost penalty.

A typical example of the impact of variations between actual and forecasted growth can be demonstrated by a "smile" curve shown in Fig. 3. Here, the ratio of cable to carrier costs is plotted as a function of variations from the forecasted growth on the assumption that both plans are equally good if the original forecast holds. Fig. 3 indicates the substantial advantages that a carrier system has over cable and, hence, its importance in urban areas which are often characterized by rapid and volatile growth situations.

Special Services Provisioning over Carrier

Savings in copper is not the only dominant economic factor in provisioning special services as explained above. The cost of loop treatment, which can be in the range of $300-1000, can often tip the balance in favor of carrier systems. With carrier, the amount of loop treatment is significantly reduced as the RT is placed close to the served subscribers. Often, the workload is reduced to installing plug-ins at the CT and the RT. This reduced workload allows shorter lead times (a few days) to provision the service. Also, because the investment is basically in the plug-ins, which can be removed when service is no longer required and used elsewhere, the chances of recovering the investment are considerably enhanced. Further savings can be realized if the special service circuit, once encoded in the carrier remote terminal, is directly interfaced to the PCM trunk network used between central offices, as shown in Fig. 4. Savings result because no CT line cards and channel banks are required.

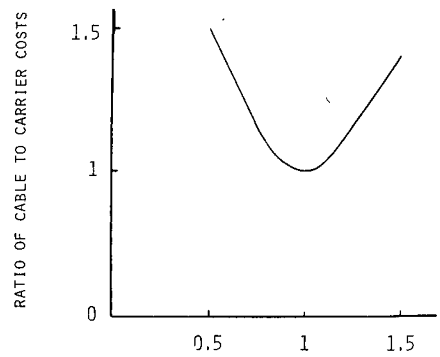

Fig. 3. "Smile" curve.

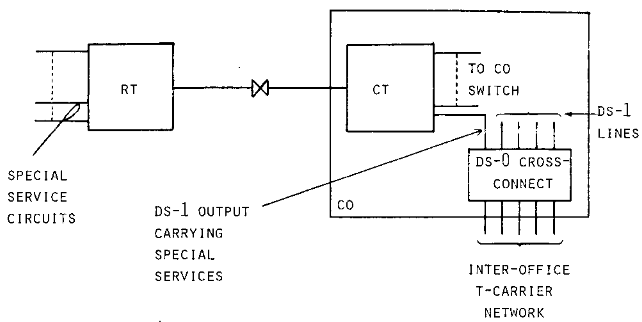

Fig. 4. Special services direct interface to interoffice T-carrier network.

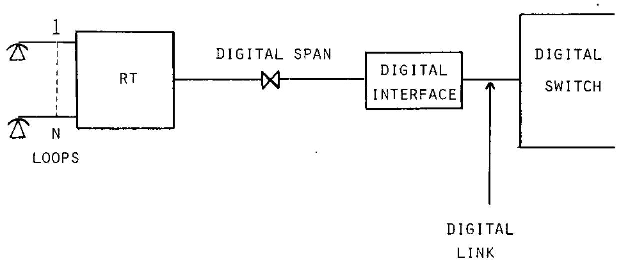

Fig. 5. Direct digital interface for urban carrier system.

Integrating Pair-Gain into Digital Switches

The integration of digital subscriber carrier into local digital switches can bring about significant cost benefits to the telcos. For this, the CO terminal is replaced by a simpler digital interface (DI) to directly link the RT to the switch (see Fig. 5). This effectively avoids the line interface cards at both the CT and the digital switch. If these cards are at a price level of around \$75 per line, then the savings of \$150 can reduce the prove-in distance of digital carrier by over 5 kft.

This capability also allows the outside plant planners a great deal of flexibility in these transitional times of analog-to-digital switch conversion. They can plan their outside plant relief program using digital carrier systems without being seriously impacted by the switch conversion programs.

PENETRATION OF CARRIER IN URBAN AREAS TODAY

The penetration of digital carrier in urban areas has been low to date. This is due to a number of limitations on the existing carrier systems such as the following.

1) High system costs restrict applications to rural areas.

2) Limited service capability which is acceptable in rural areas; in urban areas both POTS and special service capability are required.

3) Limited traffic capacity—urban areas with a significant business population require a higher traffic capacity without engineering constraints.

4) Limited maintenance capability—urban applications base is large, requiring a more sophisticated maintenance capability for both the system and the loop beyond the remote terminal.

5) Higher reliability—urban systems have to match the reliability of the shorter lengths of feeder cables they replace; special features would be required to improve the system reliability.

6) Large unsightly cabinets—placements of cabinets in urban areas can be difficult; cabinets have to be small and esthetically pleasing.

7) Limitations of the urban outside plant, e.g., manhole congestion which can make it too expensive to use the conventional T1 lines; span-lines with longer repeater spacings than T1 are thus required.

NORTHERN TELECOM'S URBAN CARRIER SYSTEM

The success of Northern Telecom's DMS-1 system (installed base of over 1500 systems) in the rural areas stimulated an interest in an urban carrier system. An urban system is now being developed by Bell-Northern Research to complement the DMS-1 system which has been designed for rural applications.

The DMS-1 urban carrier system has a capacity of 544 lines and consists of an outside plant located remote terminal (RT) connected by means of digital span lines to a CO terminal (CT). The architecture of the two terminals is similar and in a number of cases shares identical circuits. The terminals can be split into modular common and line equipment.

The line equipment interfaces the subscriber lines to the system. It consists of a single line codec for the analog-digital conversion and the necessary interfaces to the various types of urban services, such as single party POTS, voice special services (FX, OPX/S, WATS, tie-trunks, etc.) and data (digital and analog) services.

The common equipment consists of nonblocking time-slot-interchange (TSI), common control (CC), and maintenance modules. The CC handles the call processing, fault diagnostics/recovery, and control of maintenance functions. The maintenance module provides two levels of man-machine interface—a local interface at both the CT and the RT consisting of an alarm/test panel and a remote interface consisting of a teletype terminal. This terminal can be shared by up to eight separate systems. A loop testing capability which can be controlled from the Repair Service Bureau can be provided either through a metallic bypass pair to isolate the physical loop from the system or through a test-head located in the RT.

Up to eight T1 lines or equivalent fiber span lines can be used per system to give over 10 ccs/line traffic capability. To protect the traffic on a span line, a channel reassignment feature is provided. Through this feature, the traffic on a failed line is automatically transferred to available channels on other span lines without dropping connections at the CO switch.

The overall system features a very compact design. A complete 544-line system can be equipped on a 7 ft bay at the CT and in a weatherproof cabinet of dimensions 58 in by 60 in by 20 in at the RT. The cabinet has been designed to blend well with the urban surroundings.

SYSTEM TRIAL

A system trial has been arranged for the Northern Telecom urban carrier system in Bell Canada's Hull central office in Quebec. The trial will be in progress during the summer of 1982. The aim of the trial is to demonstrate the technology, the design, and the suitability of the system features for urban applications.

SUMMARY

With the improvements in technology, it is now possible to design pair gain systems for applications in urban areas. Urban system features are in many ways different from rural systems, and hence a special design is required. There is a potentially very large application base for urban systems because of the increasing cost of provisioning service over physical copper pairs.

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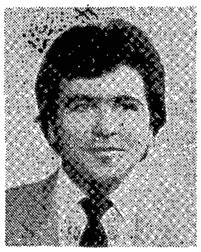

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