COST EFFECTIVE CABLE TELEVISION TRANSPORT FOR PCN

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ABSTRACT

A novel approach for universal transport of PCN signals on Cable Television facilities is described. Experimental Remote Antenna Driver (RAD) hardware has been tested on Cable Television facilities in a variety of user environments including residential, office and shopping mall. Network architecture evolution based on fiber optic signal transport supports consumer demand paced capital deployment. Bidirectional cable transport, essential for PCN is discussed. A comparison with standalone base-station deployment is made.

INTRODUCTION

Many believe that Digital Cordless Telephone (DCT) service represents the next major step in the evolution of wireless telephone service in North America, with the potential to make wireless telephone service available to all consumers and to lead the way to the personal communications environment, where a single telephone number could reach users no matter where they are located[1].

Moreover, cable television companies have a potentially important role to play in this challenging vision of the future for personal communications[2].

An ubiquitous wireless telephone service will require a large number of base-stations to be deployed. In order to provide high quality service in an affordable technology package these base-stations will need to be closely spaced and will require a means of connection to the public switched telephone network.

The deployment and interconnection of these many base-stations with the Public Switched Telephone Network (PSTN) requires a substantial telecommunications network. The entities currently in the best position to provide this Personal Communications Network (PCN) include the telephone companies, cable television operators, alternate access carriers, and private communications network owners including the power utilities.

PERSONAL COMMUNICATIONS SERVICES

Achieving a successful consumer acceptance of Personal Communication Services (PCS) requires that these new communications services have the following characteristics:

- good service quality: a grade of service defined as percentage calls blocked plus 10 times percentage calls dropped totalling less than 0.5 percent of total call attempts;
- extensive network coverage: general availability of service where people are;
- a highly accessible retail network for the marketing and sale of subscriptions to the wireless telephone service;
- efficient business office and customer services, sensitive to local market needs;
- a diversity of services and service features, including virtual private networks for business users; and
- excellent price value, based on exceptionally cost-effective network design and operation.

Users of PCS will expect to have access to basic telephone service features such as operator services, long distance calling, credit card calls, directory assistance and emergency services.

In addition, service providers will consider enhanced telephone service features including call management services and voice store and forward. These service features will be accompanied by network design features such as autonomous registration, which will allow users to make and receive calls no matter where they are.

NETWORK REQUIREMENTS

The low-cost, lightweight transceivers associated with PCS will necessitate low transmit power, in the vicinity of 10mW[3]. The resulting limited radio path loss budget supports a typical outdoor base station service radius of 150m hence requiring a very large number of radio base-stations to provide the extensive availability necessary for a successful service.

The PCN necessary to support the numerous base-stations must satisfy the following criteria; widespread, reliable, low-cost, flexible, and support sufficient traffic capacity. A brief description of each parameter follows.

Widespread

Users' reasonable expectations of widespread PCS availability means the network of base-stations needs to extend into most urban and suburban areas. Those existing communications networks already close to meeting this requirement are advantageously positioned to provide base-station signal transport.

PCS availability will be expected in most public areas such as playgrounds, parks, sidewalks, and within buildings such as airports, shopping malls, recreation facilities, hotels, stadiums, ice rinks, and variety stores; in short, wherever a person is likely to spend more than a few moments.

Reliable

The Grade Of Service (GOS) suggested above (0.5%) for successful PCS depends on a combination of critical elements. Traffic capacity related elements are treated later in this paper. The GOS budget is mainly allocated to the radio link, which is subject to significant shadowing and multipath fading in the low-power, high-clutter environment anticipated for most PCS base-stations[4].

The telecommunications infrastructure portion of the PCN must therefore achieve virtually 100% availability in order not to affect the overall GOS. A single component should not affect a large number of base-stations, implying a need for redundancy and fail-safes inherent in the network architecture. Maintenance activities must not result in frequent service interruptions. Expeditious repair of equipment failures is mandatory.

Low-Cost

Two elements dominate the total cost of operating a PCN: purchase and installation of base-stations and interconnect network operating costs. The interconnect network between base-stations can easily become the greatest operating cost element in PCS delivery. Achieving an affordable rate structure commensurate with widespread service penetration necessitates a low-cost communications network.

The interconnect network may also contribute indirectly to the base-station costs. Removing as much signal processing as possible from the base-station will in general reduce its complexity, power consumption (another significant operating cost) and manufacturing cost.

Flexible

A large degree of uncertainty exists among wireless telephone experts as to the details of how PCS will evolve. The desire to easily add or change services is driving the current intelligent network (IN) developments in the telecommunications industry. Unfettered evolution of PCS will require IN capabilities in the support infrastructure of base-stations and interconnect network.

The inexact radio engineering for thousands of base-stations (precision engineering would be prohibitively expensive) will require that individual stations be easily added or moved by relatively unskilled technicians working autonomously in the field. The base-station interconnect network must therefore be easily and cost-effectively extended to practically anywhere in urban and suburban areas.

Capacity

Together with network reliability discussed above, proper matching of traffic channel capacity with user demand at any particular location determine the GOS. Unsuccessful call attempts resulting from a shortage of voice channels are reduced by the addition of base-station equipment, which the interconnect network must be capable of supporting. PCS demand is expected to be low when the network is built, and subsequently grow with time as service penetration increases. Perspective PCS providers face the challenge of achieving sufficient traffic capacity at low cost when building the base-station network while ensuring expansion capability as the service matures.

CABLE SYSTEM SUITABILITY

The possibility of cable television systems providing the PCN was suggested earlier in this paper. Cable's ability to meet the requirements listed above will now be reviewed.

Widespread

Cable television systems currently serve virtually all urban and suburban areas in North America. Areas typically poorly served are commercial and industrial areas. Cable facilities criss-cross residential areas in a tree-and-branch architecture which passes 95% of all TV households and many public buildings.

These extensive coaxial networks are typically one-way, however. Most of the amplifiers must be upgraded to bi-directional operation and properly aligned to support a PCN.

Many cable operators are exploring business communications opportunities in urban centers, leading to network expansion in traditionally poorly served areas. These extensions are frequently fiber-optic based two-way systems.

Reliable

The network availability required to support PCS is generally not supported by cable television operators. This is one parameter that cable owners will need to examine closely in their deliberations of PCS involvement.

Technical operating and Maintenance practices vary across the industry with extended service outages common in significant portions of cable networks. Many operators who have tried to use the coax networks for supporting business communications have invariably become frustrated and installed fiber systems to deliver the quality of service expected by the customer. A radical change in technical operating philosophy is required by most cable operators before serious exploitation of existing coax facilities for PCS can be realistically achieved.

Network reliability improvements are realized through system architecture and equipment modernization in addition to maintenance practices. The current deployment of fiber to serving areas of approximately 2000 homes reduces significantly the number of components between the headend and the customer with attendant lower probability of failure[5,6]. Status monitoring of system actives enables rapid response to equipment failures. Amplifier bypass reduces the impact of failure, supporting "lifeline" service continuation until repairs are made. Standby powering of components serving a substantial number of customers further reduces service outages. The PCS availability expectations may require all actives be standby powered.

Two-way plant operation introduces additional challenges. Ingress in the traditional upstream band 5 to 33 MHz can significantly impair communications. The objective of meeting Cumulative Leakage Index (CLI) requirements for aeronautical band occupancy on cable should simultaneously give satisfactory ingress immunity. Technician training for proper two-way alignment and maintenance procedures is required. Success among various operators shows two-way operation is possible but only through a comprehensive commitment to incorporate upstream system design and maintenance into the cable system operation.

Low-Cost

The extensive cable distribution networks which already exist in residential areas can be combined with an innovative signal processing concept to extend high quality, cost-effective wireless telephone service to all public areas in a neighbourhood, including streets, parks, hospitals, plazas and school yards.

Under the authority of an experimental license granted by the Canadian Department of Communications, Rogers Cable is undertaking a field trial of cordless telephone technology in

Vancouver, Canada. This trial, which commenced on September 26 1991, is designed to test the performance of CT2 Plus technology produced by a number of different manufacturers. In addition, this field trial is designed to test the feasibility of a wireless signal processing concept developed in conjunction with Cable Television Laboratories Inc.

This new concept, referred to as remote antenna driver (RAD), uses cable distribution plant, equipped with two-way amplifiers, to connect a number of remotely located antennas to centrally located base-stations. In this way, an extensive coverage area capable of accommodating many users may be established without the need to deploy numerous base-stations. This not only improves the cost-efficiency of the network but also provides for continuous uninterrupted service as the user moves from antenna to antenna within the coverage area.

RAD technology will be particularly effective in providing wireless telephone service in residential areas where there is an installed base of cable distribution plant and where the cost of providing extensive coverage of public areas using conventional base-station technology would be prohibitive.

Flexible

The deployment of RAD on the existing broadband coaxial cable television networks is an ideal means for supporting a growing PCS customer base. Through the sharing of base-stations over an extensive area of low traffic, optimum base-station acquisition for the number of users is achieved.

Intelligent Networks (IN) enable a variety of advanced telecommunication services of interest to wireless telephone customers. Advanced call routing and termination, dynamically controlled by the user and provided through IN gives the customer the choice to accept certain calls while sending other calls to voice-mail, with the selection particulars dependant on location or time of day. The concentrating of base-stations at a limited number of locations eases IN implementation by reducing the quantity of sites requiring separate IN interconnect facilities.

The virtual base-stations that RAD units represent increase installation flexibility through ease of deployment anywhere within a cable television system. Adaptive subsystems within the RAD conform to the cable environment with a minimum of technician support.

Capacity

Additional base-stations are easily added, while frequency division multiplexing on coax and ultimately space division multiplexing on fiber allow unrestricted expansion of traffic capacity. The expected continuation of fiber deployment in cable systems leads to ever smaller areas of shared coax facilities. Supporting PCS via a "last mile" of coax is therefore practical even as user traffic increases.

THE RAD TECHNOLOGY

Cable Television Laboratories and the engineering staff within the Rogers family of companies, including Rogers Engineering, have developed a method for remoting antennas relative to wireless base-station equipment. This work finds potential application in micro-cellular and PCN deployment. A number of experimental installations of antennas connected by coaxial cable to host base-stations have been tested for micro-cellular with good results.

The concept of remoting antennas from a set of radio base-stations is considerably enhanced if a standard CATV distribution system were able to provide the connection. The evolution in cordless telephone technology towards PCS makes this a very desirable means for serving an extremely large number of small micro-cells. The likely frequencies to be used for PCS (ie. 1850-2200 MHz) are, however, beyond the normal range of CATV systems. Therefore a conversion process is needed at each remote antenna connected to the cable system.

The primary goal of the remote antenna link is transparency for voice modulated wireless radio signals. The "radio" link protocol between base-stations and portable telephones must remain uncorrupted to maintain full capabilities for call hand-off and radio channel assignment. Therefore a unity gain, broadband path for both downstream and upstream signal flow is preferred.

The CATV plant and any signal processing equipment used to transport wireless telephone signals between base-stations and remote antennas should match the operating bandwidth and dynamic range of the base-station. The technical challenge is to develop a device which can interface between the RF requirements of PCS and the limitations of existing CATV plant.

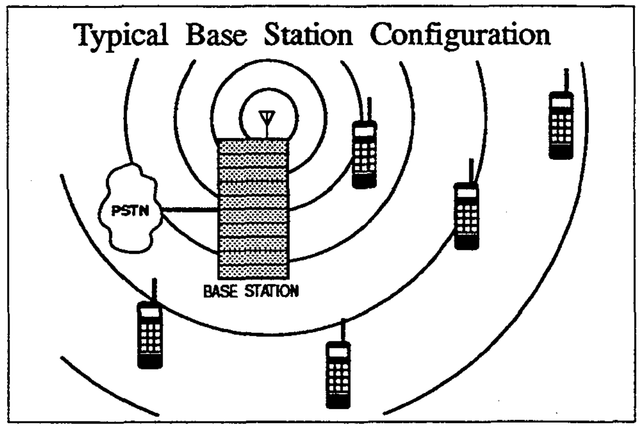
The Remote Antenna Driver (RAD) is an attempt to create such an interface device. It has proven feasible in a variety of RAD field trials to convey wireless telephone signals over standard two-way cable television facilities with no adverse effects. It has also been shown that antenna-to-antenna service continuity is practical. This is extremely useful as it trivializes the hand-off process between micro-cells.

The amount of processing required for CATV transport of PCS signals has a direct impact on both the cost and performance of the service. The minimum equipment required at each micro-cell for wireless communication is a radio transmitter and receiver. If simple amplifiers are sufficient for this task, a minimum-cost base-station is achieved. Any further processing, regardless of production volumes, is at incremental cost. In addition, processing will potentially degrade service quality or feature functionality as a result of efforts to reduce its cost.

RAD CONCEPT DESCRIPTION

The RAD concept can best be understood through a progression that starts with a single multiple voice-channel cordless telephone base-station as shown on Figure 1. The number of users able to simultaneously communicate with the base-station equipment is determined by its voice channel capacity. All users are free to roam anywhere throughout the coverage range assumed to be path-loss limited. Call setup and maintenance is per the Common Air Interface (CAI) specifications for the wireless radio protocol. A number of alternative CAI proposals have been submitted to the FCC for consideration as a PCS standard. The CAI particulars do not affect this RAD discussion. The base-station equipment connects to the PSTN via any of a variety of access technologies. The introduction of RAD concentrates this PSTN connection.

Figure 1



The next step in the progression to RAD considers an extension of the base-station equipment coverage area through a simple coaxial connection to a remote antenna as shown in Figure 2. All of the voice channels supported by the base-station appear at both antennas. A user may freely roam throughout the overlapping coverage areas provided by the two antennas with no hand-off processing required.

Figure 2

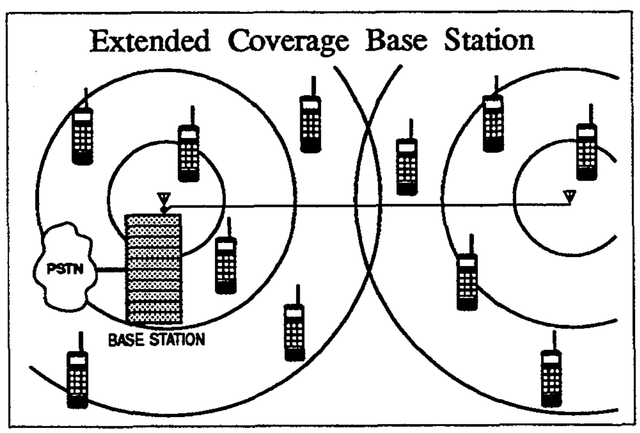
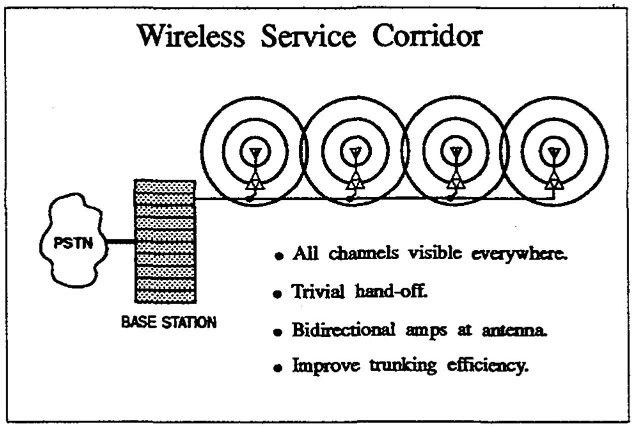


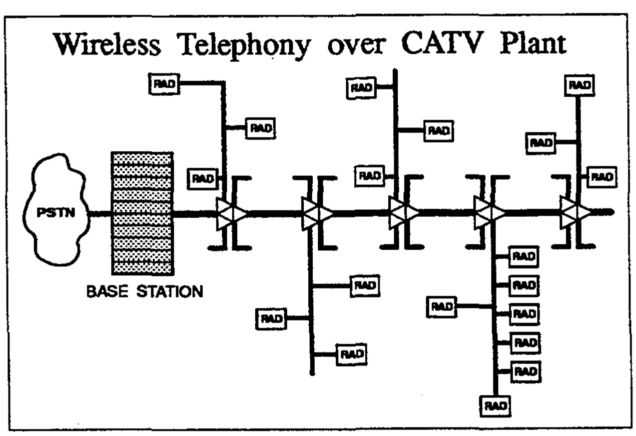
Figure 3 illustrates an extension of the remote antenna concept. A cascade of couplers and antennas served by a coaxial cable connected to the base-station antenna port supports the creation of a corridor of service coverage. Amplifiers at each antenna compensate for the attenuation of the couplers and cable. Bidirectional amplification is made possible with duplexing filters in Frequency Division Duplexed (FDD) CAI or an RF switch in Time Division Duplexed (TDD) CAI. Users have access to the full channel capabilities at any antenna and may roam without service interruption throughout the coverage corridor. The total capacity in the corridor is determined by the base-station capacity, but there is no restriction on how the capacity is shared between antennas.

Figure 3



The RAD replaces the bidirectional amplifier at each antenna. A CATV distribution system, depicted in Figure 4, connects RADs and the remote antennas they serve to a common set of base-station radios. Users at any RAD have access to the full capacity of the base-station equipment and are free to roam between overlapping RAD coverage areas without a hand-off process required. Similarly, the capacity of the base-station is shared among the RADs with no restriction. The ideal RAD is capable of full flexibility in call capacity and coverage range while not impairing the signal transmission between remote antennas and base-station radios.

Figure 4



VOICE CHANNEL PROCESSING

Implementation of PCN requires intelligence to locate wireless handsets wherever the user may be. A large number of complex radio base-stations must be deployed to provide sufficient radio access to stimulate use by the general public for PCS to succeed. Each radio base-station translates the duplex voice signals from its twisted pair or fiber optic transmission format, into radio frequency (RF) signals suitable for communication with the portable handset.

In most of the proposed PCN standards, the radio spectrum is divided into a number of discrete RF channels using Frequency Division Multiplexing. Additionally, some systems such as CT-3 employ Time Division Multiple Access (TDMA) to multiplex several traffic channels into each RF channel. In all cases, traffic channels are processed individually at the base-station before interconnection to the PSTN occurs.

Each radio channel served by the base-station generally requires a modulator and demodulator for radio communications with handsets, a multiplexer and demultiplexer for handling the transmission of voice and signalling information over the radio link and a control system for error correction, establishment of radio links, synchronization, and other functions related to digital radio transmission. An encoder and decoder for converting the voice messages into digitally-coded streams of data are required for each traffic channel.

When more than one user is served by a base-station, duplication of the circuitry for one duplex conversation or voice channel is needed for each simultaneous user. The number of users who can access a particular radio base-station will therefore be limited to the number of voice channels it is equipped to support.

PSTN Interconnect Requirements

A PSTN interface to many individual stand-alone radio base-stations requires additional loop facilities throughout the community. Each channel of each radio base-station demands a new telephone line which may be supplied by new or existing telephone company facilities or alternatively by

CATV facilities. In most cases, new transmission equipment will be needed to service this demand and the CATV operator will not have any advantage relative other network providers. Additional intelligence must be provided to locate DCT handsets wherever the user may be. Providing the intelligent network required to support the enhanced service features at all base-stations will be a difficult challenge, particularly if they are widely dispersed. Cable operators may have particular difficulty addressing this challenge using conventional telecommunication approaches.

Individual base-station package deployment requires capacity engineering for each. A determination of the number of voice channels to support at each radio base-station package must be made based on the user traffic anticipated. Most cases require at least two voice channels to adequately support users for call blocking less than 0.01. Generally this is more capacity than needed, particularly at service launch. Excess capacity at each radio base is cumulative and a less than optimum deployment of equipment results in excessive cost of PCS provision.

An Alternate Approach

In contrast to the dedicated PSTN loop interconnect configuration associated with many stand-alone base-stations, RAD deployment requires minimal consideration for the amount of voice traffic expected. A common set of base-station equipment serving a large number of RADs supports dynamic adaptation to traffic patterns throughout their collective coverage area. Traffic engineering efficiency is greatly improved since base-station capacity is determined for the neighbourhood, rather than each individual base-station.

Consumer Demand Paced Investment

As subscriber penetration increases the number of base-station channels can be increased on a very cost effective basis. Conventional telephone traffic engineering practices rely on "trunking efficiency" resulting from many users sharing a large pool of voice channels. This is illustrated in Table 1 which is taken from Erlang B load vs. loss curves. For example, a thirty-channel equipped base-station with the assumption of 0.1 Erlangs per user will support 200 users within the area served by those base-stations, with a probability of busy signal of less than one percent. One Erlang is equivalent to a single telephone line busy for one hour. A sub-unit commonly used is hundred (centum) call seconds (CCS), with 36 CCS in one Erlang. A user offering 0.1 Erlang is therefore using one phone line (or voice channel) for a total of 6 minutes every hour. In this case 7 users share each base-station voice channel. A radio base-station with 7 channels only supports 20 users, with only 3 users sharing each channel.

TABLE 1
WIRELESS VOICE TRAFFIC CAPACITY

Neighbourhood Population	2000	2000	2000	2000
DCT Service Penetration	1%	5%	10%	25%
User Population	20	100	200	500
Voice Traffic (@0.1E)	2E	10E	20E	50E
Voice Channels Required (P(b) = 0.01)	7	18	30	64
Users per channel	3	6	7	8

The figures in Table 1 indicate the growth in channel capacity required for service penetration from 1% to 25%. It is clear from this table that even at 25% penetration, only 64 channels of voice capacity are required to service the 500 users that this level of penetration represents. The case of very low penetration is not indicated. However, for a guaranteed probability of blocking to be less than 1%, it is essential that a minimum of two voice channels be available for the user population. This rule can be applied to the stand-alone base-stations that might be deployed to offer this service to the general public. In other words, virtually every base-station installed in a public area would need to provide at least two voice channels of capacity in order to offer a level of service comparable to wire line telephone availability.

The 2000 home residential neighbourhood dimension used in the Table is consistent with coax cable plant networks resulting from deployment of fiber to the serving area. It bears clarifying that the 30 channels required for a 10% service penetration implies a 30 voice-channel radio base-station located at the headend for each serving area fiber node. An equivalent level of service requires approximately 80 individual base-stations in order to provide ubiquitous coverage over each 0.8 mile^2 area this represents. Instead, a similar number of very simple RADs are deployed at a fraction of the cost of complex radio base-stations.

A comparison of the two alternatives is presented in Table 2. The same 2000 home serving area used in Table 1 covers 0.8 mile^2, requiring 80 micro-cells of 25 homes each. The micro-cells are served by two-way coax and use either a standalone base-station or alternatively a RAD with base-station equipment concentrated at the headend.

Voice channel requirements are based on Erlang "B" curves with each user offering 0.1E (3.6 CCS) busy hour traffic load and a 0.01 call blocking probability.

TABLE 2
RAD DERIVED EFFICIENCY

	PCS PENETRATION	1%	2%	5%	10%	25%
Stand	Users per cell	0.25	0.50	1.25	2.5	6.25
Alone	Traffic per cell	0.03E	0.05E	0.13E	0.25E	0.63E
Base	Voice Channels /Cell	1	1	2	3	4
Stations	Base-station/ Cell	5	5	6	7	8
(A)	Cost/Area	400	400	480	560	640
(B)	Voice Channels /Area	80	80	160	240	320
	Users per area	20	40	100	200	500
RADs	Traffic per area	2.0E	4.0E	10.0E	20.0E	50.0E
(C)	Voice Channels /Area	7	10	18	30	64
	Base-Station Cost	7	10	18	30	64
	RAD Cost	80	80	80	80	80
(D)	Total Cost/ Area	87	90	98	110	144
	C/B	0.09	0.13	0.11	0.13	0.20
	D/A	0.22	0.24	0.20	0.20	0.23

The cost comparison, D/A, in Table 2 is relativistic, normalized to the complexity of a RAD. Concentrated base-station equipment at the headend is assumed lower cost than standalone due to more favourable packaging and environmental requirements. In the case of CT2 Plus, which uses FDMA, each voice channel requires an incremental radio transceiver and voice processing unit which is assumed equal in cost to a RAD suitable for outdoor mounting.

The significant savings in voice channel trunking required resulting from RAD is indicated in the ratio C/B. Voice traffic is concentrated when using RAD, reducing the network interconnect volume.

In effect the total number of users in the neighbourhood share the total number of base-station channels. On average, this means fewer total channels are required to support a given population of users, as documented in the Erlang traffic tables. Provided the total capacity of the shared base-station equipment is not exceeded, low probability of blocking is efficiently achieved. The expense associated with the construction and operation of a PCN is potentially reduced by the use of RAD technology deployed through existing cable distribution networks.

RF Hand-off

Connecting RAD access-ports spaced approximately 200 m apart via a cable system as depicted in Figure 4 provides contiguous coverage to form a neighbourhood area of service. A portable handset is free to move about within the cluster of contiguous antenna areas because it remains "connected" to the same base-station and no hand-off processing is required as it moves from one antenna zone to the next. This is contrasted with the conventional approach of individual base-stations at each antenna location, where a coordinated hand-off process is required for roaming. The neighbourhood extension of radio base-station service coverage is efficiently achieved with the RAD system.

CONCLUSION

In summary, the advantages of the RAD system can be listed as follows:

1. Efficient extension of coverage to areas where user density is much lower than is supported by individual base-station deployment. The cost effective deployment of PCS to the mass-market in particular is achieved via the existing cable infrastructures found in virtually all neighbourhoods.

2. The provision of seamless coverage between micro-cells such that a user may roam from one micro-cell to the next without creating a large switching burden.

3. The seamless hand-off between micro-cells supports focused coverage patterns such as streetscapes and pedestrian malls.

4. Small micro-cell electronics package (RAD) for unobtrusive mounting on buildings, street light standards and utility poles.

5. The concentrating of base-stations optimizes the number of voice channel interconnects required over the total area of the system. This also facilitates advanced network interconnect necessary for the anticipated service features.

6. Consumer demand paced equipment deployment is achieved through the concentrating of radio base-stations made possible by RAD.

7. Elimination of micro-cell capacity engineering, significantly reduces the cost of adding service coverage.

Through innovative techniques, cable operators may succeed in efficiently and cost effectively transporting wireless telephone signals for PCS providers. However, significant improvements in plant reliability and upgrades to two-way operation will need to accompany techniques like RAD and fiber deployment to provide an interconnect facility applicable to these new communication services.

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REFERENCES

[1] D.J. Goodman, "Trends in Cellular and Cordless Communication", IEEE Communications Magazine, Vol. 29, No. 6, pp. 31-40, June 1991.

[2] A.D. Roscoe, A.S. Taylor, "PCN In Cable TV's Strategic Plans", NCTA Technical Papers, pp. 146-156, 1991.

[3] D.C. Cox, "Personal Communications - A Viewpoint", IEEE Communications magazine, Vol. 28, No. 11, pp. 8-20, 92, November 1990.

[4] P.E. Mogenson et.al., "Urban Area Radio Propagation Measurements at 955 and 1845 MHz for Small and Micro Cells", Conference Record, IEEE Globecom, pp. 1297-1302, 1991.

[5] J.A. Mattson, "Fiber to Feeder Design Study", NCTA Technical Papers, March 1991.

[6] J.A. Vaughan, "550 Upgrades With Fiber: Selecting Cost-Effective Architectures", NCTA Technical Papers, March 1991.

BIOGRAPHY

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Mr. Hart has most recently been devoting his attention to PCN and managing the development and field testing of RAD. Prior to this he developed the Rogers Fiber Architecture and managed the procurement and deployment of fiber optic equipment required to implement the architecture within Rogers operating divisions.

Mr. Hart has also managed pay television security system development and two-way interactive system deployment for Rogers. He has been monitoring HDTV and digital video compression and regularly participates in the quarterly reviews of Canadian CableLabs Fund research and development projects.

Mr. Hart is a member of the Association of Professional Engineers of Ontario, Canada, the IEEE and the SCTE.