PCN IN CABLE TV'S STRATEGIC PLANS

Archer S. Taylor, Senior Vice President
Malarkey-Taylor Associates, Inc.

Andrew D. Roscoe, President
Economic and Management Consultants International, Inc.,
A Malarkey-Taylor Company

ABSTRACT

Personal Communications Networks (PCN) will be an important new service for cable operators when commercial licensing begins in the mid-1990s. The technological and marketing synergies with cable TV make these services an inviting opportunity for cable companies in telephony. The potential synergy of cable TV and PCN has prompted several multiple cable system operators (MSO) to seek authority from FCC to conduct technical and marketing experiments. PCN is a network of advanced digital tetherless telephones, technologically similar to the mobile cellular services but using much more closely spaced microcells, and small cordless handsets suitable for pedestrian use. Low power and spread spectrum techniques are proposed to minimize interference. The disappointing experience in the U.K. with the more limited CT-2 is believed to be primarily a result of excessive haste in granting the four licenses, and in launching the service in April 1990 without fully developed, compatible infrastructure. Three PCN licenses have been awarded in the U.K, with commencement of service not expected before 1992 or 1993. EMCI has conducted extensive research on the market potential for CT-2 and PCN in the U.S. The phenomenal growth of cordless telephones, paging, and cellular telephones in the U.S. suggests significant public demand for truly tetherless personal communication facilities. The capital requirements and operational characteristics of microcell services will differ significantly from services such as cellular due to different system configurations.

INTRODUCTION

Cable TV has long claimed to be an important telecommunications medium. Twenty years ago, the Chairman of the Federal Communications Commission, Dean Burch, told the NCTA:

> *...that it's up to you whether cable is going to be just another way of moving broadcast signals around (hardly worth the ulcers involved) or whether it is going to become a genuinely new and competitively different medium of communications...*

It has been a long time coming, but, in answer to Dean Burch's challenge, cable TV appears finally to be at the threshold of the brave, new world of Personal Communications.

Personal Communications means people communicating with people, without being tethered to a phone jack, wherever they may be: at home, in the backyard, at the office, at the beach, in the grocery store, at the airport, in the car, or just walking down the street.

WHAT IS PCN?

PCN stands for Personal Communications Network, today's hot buzz-word in telecommunications.

PCN is a subset of the family of Personal Communications Services (PCS) that includes the entire gamut of tetherless telephony services.

PCN is a network of advanced digital tetherless telephones, technologically similar to the mobile cellular networks now operating throughout the world. The digital mode assures much higher quality voice transmission and substantially greater privacy than is possible with the present analog cordless telephones.

PCN is being touted as a *radio drop* that is much cheaper to install than standard copper access lines.

Personal Communications Services

VEHICULAR CELLULAR

Mobility:	*Use in moving vehicles on streets and highways almost everywhere in the U.S.*
Information Content:	*Voice communication - incoming and outgoing calls*
Price per Month:	*$80*
Size:	*Briefcase*
Battery Life in Use:	*Indefinite (uses vehicle battery on continuous charge)*

LARGE HANDHELD CELLULAR

Mobility:	*Use in or out of moving vehicles, almost everywhere in the U.S.*
Information Content:	*Voice communication - incoming and outgoing calls*
Price per Month:	*$100*
Size:	*Standard phone*
Battery Life in Use:	*1 week*

SMALL HANDHELD CELLULAR

Mobility:	*Use in or out of moving vehicles almost everywhere in the U.S.*
Information Content:	*Information Content: Voice communication - incoming and outgoing calls*
Price per Month:	*$100*
Size:	*Man's wallet*
Battery Life in Use:	*1 day*

WIDE AREA PAGING

Mobility:	*Use in or out of moving vehicles and carry on belt almost everywhere in the U.S.*
Information Content:	*Beeper or displayed information - receive only*
Price per Month:	*$40*
Size:	*Cigarette lighter*
Battery Life in Use:	*1 month*

STANDARD PAGING

Mobility:	*Use in or out of moving vehicles and carry on belt almost everywhere in the U.S.*
Information Content:	*Beeper or displayed information - receive only*
Price per Month:	*$20*
Size:	*Cigarette Lighter*
Battery Life in Use:	*1 month*

CT-2

Mobility:	*Use with any compatible base station in home and/or office and specified locations on the street*
Information Content:	*Voice communication outgoing calls only*
Price per Month:	*$60*
Size:	*Man's wallet*
Battery Life in Use:	*1 week*

PCN

Mobility:	*Use in home and/or office and in downtown areas*
Information Content:	*Voice communication " incoming and outgoing calls*
Price per month:	*$ 70*
Size:	*Man's wallet*
Battery Life in Use	*1 week*

COMMON CORDLESS CT-1

Mobility:	*Limited to less than 100 feet from its associated base*
Information Content:	*Voice communication - incoming and outgoing calls.*
Price per month:	*$ 5*
Size:	*Standard phone*
Battery Life in Use:	*indefinite, recharge*

Figure 1

Most cellular telephones are installed in automobiles where size and weight are not critical, and where plenty of power is available from a high capacity, continuously charged storage battery. Hand-held cellular phones are still too large and heavy for a shirt pocket or purse, and generally rely on rechargeable NiCad batteries to achieve reasonably long life in use.

The PCN handset, on the other hand, should be no larger or heavier than a wallet or small pocket calculator. It should be able to operate for a reasonable time in use with a small expendable dry-cell battery.

Cellular telephones are designed to communicate with a base station at distances up to several miles. To accomplish this may require up to 50 watts effective radiated power (ERP), more or less, at the cell site, and 1/2 to 3 watts ERP, at the mobile transmitter. When the mobile unit moves out of range of one base station, it is automatically handed off to another base station that is within range.

In order to achieve the objectives of PCN, however, battery capacity limitations mean that handsets could transmit only a few milliwatts ERP. At that level, the effective communication range would be limited to a tenth of a mile, more or less, from a microcell site. To cover just the entire downtown area of a major city would require hundreds of cell site base stations, perhaps even 1,000 to 10,000.

Because of the short coverage range of PCN microcells, vehicles travelling at highway speed might pass in and out of range too quickly for the handoff to be accomplished. For this reason, PCN is expected to be used primarily with handsets that are stationary, or perhaps moving slowly, at walking speed, for example.

PCN TECHNOLOGY

No frequency bands have yet been allocated to PCN, in the U.S. It is virtually certain, however, that spectrum will have to be shared, initially at least, with other radio services, possibly the private operational-fixed microwave service in the 1850-1990 MHz band. For this reason, spread spectrum technology is being seriously considered, here and abroad, to minimize the risk of interference between PCN and other services.

Spread spectrum is a technique developed for military use to neutralize the effect of enemy jamming. The two principal spread spectrum techniques are frequency-hopping (FH) and direct sequence (DS). As the FH term suggests, the carrier frequency is *hopped* about in accordance with a predetermined but repeatable *pseudo-random* sequence. In order to receive the signal, the receiver must be able to replicate the precise hopping pattern as it tracks the desired signal. The receiver will be tuned to an interfering signal for only very brief intervals, if at all. Moreover, the transmitter will rest for such a short time on any particular frequency that it is unlikely to cause interference.

PCN Topology

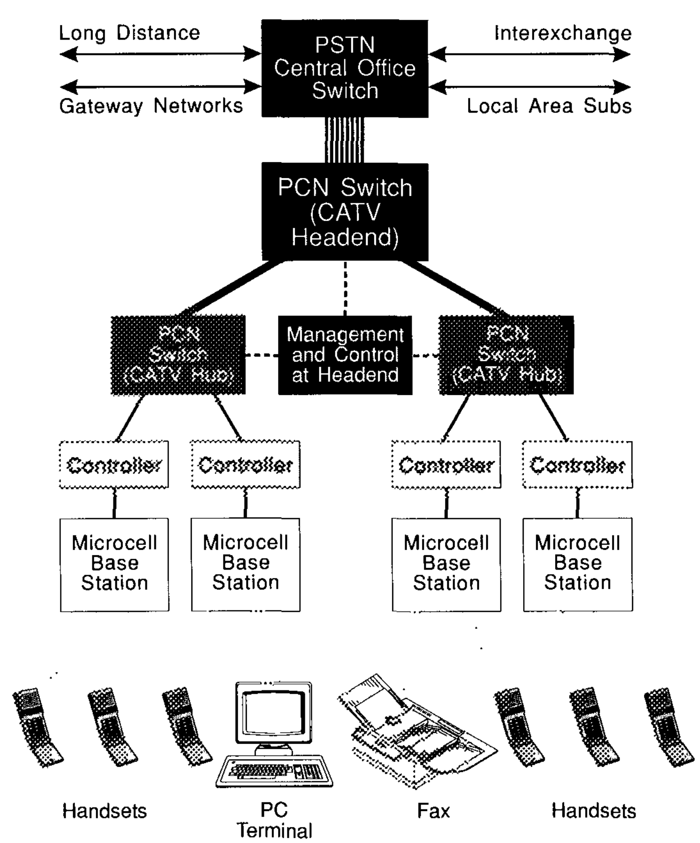

Figure 2

For *direct sequence*, the data stream is modulated with a very wideband, pseudo-random noise signal whose frequency and amplitude distribution is switched in a predetermined but repeatable manner. The data stream is recovered at the receiver by synchronously demodulating with an identical pseudo-random signal.

Access for a multitude of channels can be created in three ways. Frequency Division Multiple Access (FDMA) is comparable to the familiar FDM multiple channelling used exclusively on cable TV networks. For direct sequence spread spectrum, multiple channels can be transmitted either by Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA).

In TDMA, each signal channel is assigned a specific time interval. The receiver is synchronized to the transmission so that it can respond only during the time interval designated for the particular desired channel.

In CDMA, a different pseudo-random noise pattern (or *code*) is assigned to each message channel. The receiver responds only to the particular channel for which the pseudo-random code matches the transmitted code. Any signal that has been modulated with a different pseudo-random noise signal, or none at all, will be completely obliterated by noise that is indistinguishable from the truly gaussian distribution. Thus a fair number of digital messages, can be transmitted simultaneously in the same frequency band, using CDMA, without mutual interference.

Reception of the spread spectrum signal, whether using TDMA or CDMA requires knowledge of the precise frequency and amplitude distribution of the pseudo-random noise pattern. TDMA also requires appropriate time synchronizing data. Encrypting this information is a particularly effective way to assure the security of the desired signal against unauthorized reception without the encryption key. Privacy is an important feature of PCN not provided by analog cordless telephones.

In June, 1990, the FCC issued a Notice of Inquiry (NOI) seeking suggestions on frequency allocation and technical standards for PCN. NCTA and many cable operators filed comments, and at least eight MSOs have filed petitions for authority to conduct technical and marketing experiments. Some experimental authorizations have been granted.

THE U.K. EXPERIENCE

In the United Kingdom, PCN licenses have been awarded to three consortia including, as participating members, Pacific Telesis, U.S. West, Mercury Communications, Telefonika of Spain, Deutsche Bundespost Telekom, Millicom, Sony, and Motorola, among others. All three consortia proposed to use the GSM (Global System for Mobile Communications) standards developed by the European Conference of Postal and Telegraph administrations (CEPT) for a pan-European digital cellular network. However, they have recently funded a special committee of the European Telecommunications Standards Institute (ETSI) to decide what changes may be needed for PCN. Commencement of PCN service in the U.K. is not expected before 1992 or 1993.

Two years ago, the U.K. Department of Trade and Industry (DTI) awarded four licenses for CT-2, a limited Personal Communications Service described as an *advanced digital cordless telephone.* CT-2 is an improvement over the conventional cordless telephone (CT-1) in several important respects. First, it is digital, using FDMA. Secondly, handsets are identified for billing rather than the base station, as in conventional cordless phones. This allows calls to be originated through any compatible base station. However, CT-2 cannot receive incoming calls because it does not have the capability to scan all base stations in order to locate the particular handset. Moreover, CT-2 does not have handoff capability.

In addition to use in the home or office, subscribers can use their CT-2 handsets to make outgoing calls from any location within about 600 feet of a compatible public base station, a service called *telepoint.* PBX base stations are also being developed with which multiple handsets could access multiple office telephone lines.

Early experience in the U.K. was disappointing, primarily as a result of excessive haste in granting the licenses and bringing the product to market. The Office of Telecommunications (OFTEL) believed that rapid roll-out would secure a national network of base stations, create demand, and decrease costs.

Three of the four licensees were operational by April 1990. Yet even in the most heavily travelled pedestrian areas of London, telepoint subscribers found it difficult, if not impossible, to locate areas for CT-2 handset use. To make matters even worse, the three carriers implemented telepoint service with different and incompatible proprietary protocols, because the compatible Common Air Interface (CAI) standard protocol was not ready in time for launch. A fourth licensee postponed introducing its product until CAI was ready. It seems almost axiomatic that competing personal communications services must be compatible to succeed.

While the first year of telepoint in the U.K. appears to have been a disaster, there are reasons to believe that the market will strengthen. Base stations must be compatible with the CAI standard protocol in 1991. Recently introduced base stations for PBX and home use are expected to create significant new demand. Major investment is being made to assure easy accessibility to compatible base stations.

CABLE TV SYNERGY

Applications to FCC by several of the top 10 MSOs, and others, for experimental PCN authorizations clearly highlight the synergy with PCN perceived by cable TV network operators.

PCN microcell base stations might be located on a lamppost, or telephone pole, or building at every other street corner. Initially, they could be as large as a battery standby power supply or a small refrigerator; eventually, however, they might be no larger than a cable TV line extender amplifier.

The optical fiber star trunk topology has many advantages for cable TV networks. Coincidentally, however, it is particularly suitable for providing the multiple duplex digital voice circuits required between PCN microcells and cable TV hubs, fiber optic nodes, or headends. Whereas a telephone company might have to install new sub-carrier or broadband plant virtually everywhere, cable TV already has broadband plant in place. The 18 MHz in each direction suggested in the Cablevision Systems experimental proposal can easily be provided in sub-split cable plant. Much more could be provided with the mid-split arrangement in the Institutional Networks.

Cable TV needs only to enlarge and adapt its customer billing, customer service and maintenance infrastructure to accommodate PCN transactions. The enhanced reliability that may be demanded by PCN subscribers can be provided by installing status monitoring facilities, providing automatically switched routing and equipment redundancy, backup power (including UPS where necessary), and by improved preventive maintenance procedures.

Residential PCN Layout

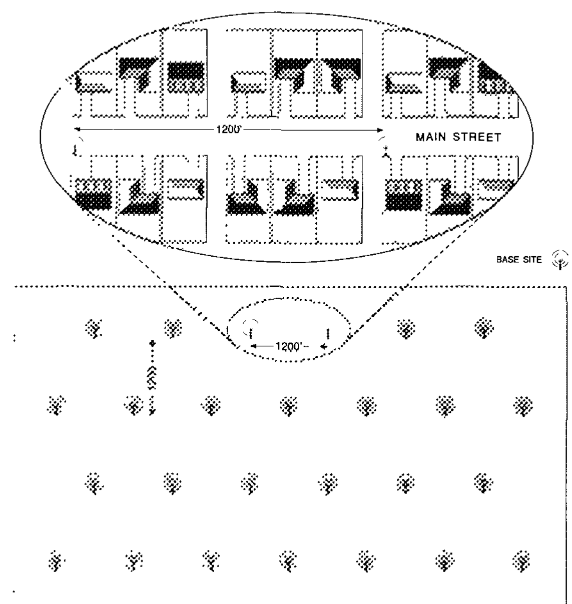

Figure 3

TELCO COMPETITION

The possibility that cable TV operators may be able to compete with the established telcos for Personal Communications subscribers is substantially enhanced by the probability that restrictions on telco entry in cable TV will be at least partially relaxed. Clearly, the trend, not only in the U.S.A, but all over the world, is to encourage competition in virtually every formerly monopolistic institution. It is simply inconceivable that telcos

Comparison of Selected Mobile Communications Technologies

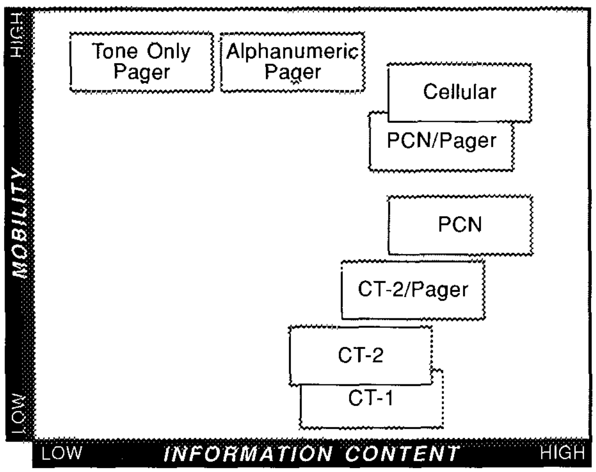

Figure 6

tions of CT-2's demand and operational characteristics are compared to PCN.

To determine the market potential for PCN and CT-2, EMCI analyzed the relative positioning of these technologies against existing mobile communications technologies, primarily cellular. Mobile communications technologies can be viewed as existing within a continuum along two axes: mobility and information content (see Figure 6). Mobility refers to the ubiquity of product use. Pagers and cellular have high mobility since they can be used nationwide. Information content relates to the degree of interaction allowed. Pagers have relatively low information content since they allow only a displayed message to be received by the user. Cellular has high information content since it allows users to send and receive voice communications.

CT-2 will compete to some extent with all mobile technologies. It, however, will also be complementary to pagers. CT-2/pager combinations will have relatively higher mobility and information content than standard CT-2 units. Due to similarities in mobility and information content, CT-2 will be most directly competitive with PCN. CT-2 and PCN will likely also be competitive with cellular, particularly if cellular reacts to these products, reducing its pricing while retaining its relatively high mobility and information content.

Through surveys and econometric analysis, EMCI has examined demand for mobile communications products. Within the price levels examined, the demand for CT-2 is roughly half the demand for cellular. The lower demand for CT-2 at a given price is due to the inability to receive calls and the restricted mobility of CT-2.

Given a price differential between CT-2 and cellular, however, CT-2 can generate demand levels similar to cellular. For example, if the average monthly bill of cellular was $70 and the average monthly bill for CT-2 was $40, there would be virtually the same consumer demand for CT-2 as for cellular (see Figure 7). PCN will generate a similar level of demand to cellular if priced at a 25% discount to cellular. The projected demand for CT-2 and PCN is a combination of new mobile communications users not interested in existing products, consumers switching from existing technologies, and consumers using other mobile communications products in conjunction with these products.

These findings, when combined with information on consumer demand for cellular and competing technologies, can be used to derive market potential estimates for CT-2. By tracking penetration trends for recently operational cellular markets, EMCI has determined that a new cellular market can expect to achieve three to five percent pene-

Preliminary Estimate of Consumer Price Sensitivity for Cellular and CT-2.

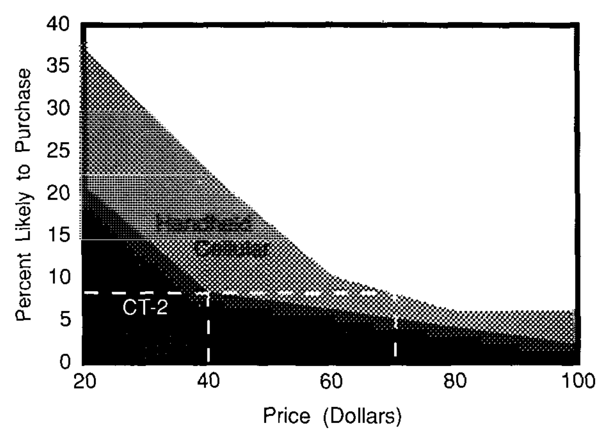

Figure 7

PCN in an Industrial Park

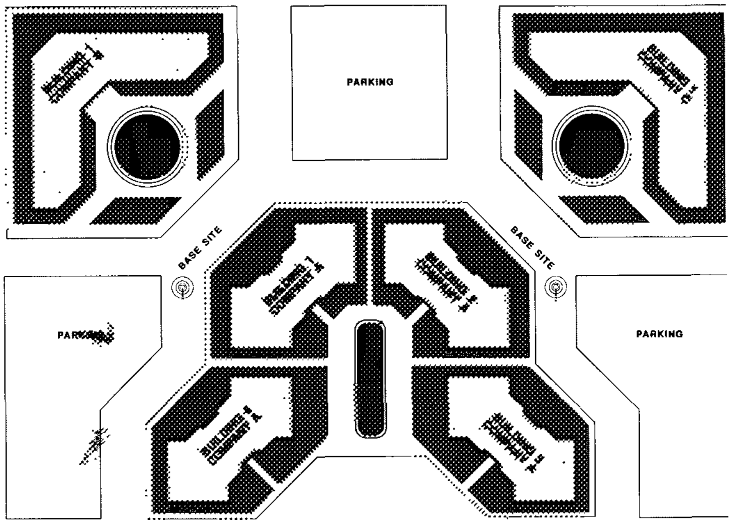

Figure 4

PCN in the Business District

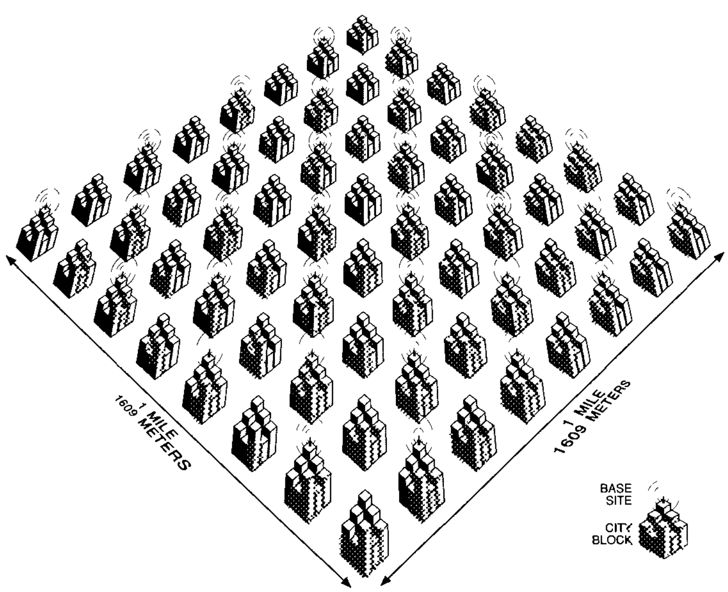

Figure 5

would be permitted to compete with cable TV without also permitting cable TV to compete for PCN subscribers.

Telephone companies, through established tariff procedures, obviously control the charges and terms for access to the Public Switched Telephone Network (PSTN). These are fairly well set for cellular and other interconnected radio communications systems, and not likely to change for PCN. However, telcos also control the charges for pole attachment and duct rental. Already, they have demonstrated apparently predatory tactics by charging as much as $120 per year for fiber optic pole attachments, compared with $5 for the coaxial TV cable on which the fiber is overlashed. This is a matter that must be confronted.

It will take patient investment strategy, lobbying, and litigation by cable TV interests to establish a solid position in PCN. Short of actually operating PCN, cable TV operators could either lease bandwidth on the existing network to unaffiliated PCN operators, or overlay independent networks for lease to PCN.

While the synergies of cable and PCN are clear, operating cost and revenue structures are not yet well-defined. The following analysis by EMCI's President, Andrew Roscoe, examines the market potential, capital requirements, and operating costs for CT-2 and PCN based on anticipated configurations. ■ *AST*

THE MARKET POTENTIAL FOR CT-2 AND PCN

Because the technology and market structure of PCN have yet to be defined, it is difficult to determine financial benchmarks for this service. CT-2, however, has been operational in the U.K. for almost two years. This section examines the market potential for CT-2 service in the U.S., followed by benchmark financial projections using several scenarios. When possible, the implica-

The Market Potential for Telepoint (CT-2) in the U.S. Top 100 Markets

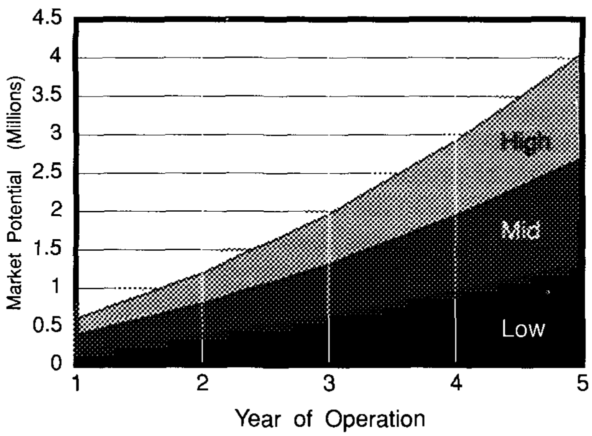

Figure 8

tration of population over a five year period. EMCI's survey research indicates that CT-2 can be feasibly priced at a discount relative to cellular such that total demand for CT-2 is similar to total demand for cellular.

EMCI estimates that the five year market potential for the top 100 U.S. markets is between 1.3 and 4.0 million, with a mid-point of 2.7 million (see Figure 8). The high market penetration estimate is based on little or no competition among other technologies and CT-2 for customers. This forecast implies that CT-2 will generate new subscribers that would not otherwise use mobile communications devices. Since CT-2 does compete with cellular for some of the same market segments, this is considered a maximum market potential. The low market potential estimate assumes that a CT-2 carrier will compete with other carriers, either other CT-2 carriers or cellular and/or PCN carriers and that CT-2 will be competitively priced relative to PCN and cellular.

While survey research indicates that PCN will generate a similar level of demand to cellular if priced at a 25% discount, several industry experts believe that it will be priced at a 50% discount to cellular. If this prediction is realized, the demand for PCN will be several times that of cellular, resulting in a potential PCN market of at least 10 million subscribers after only five years of operation. The U.S. marketplace is highly receptive to mobile communications products. Illustrative is the use of 26 million home cordless phones and over 14 million cellular phones and pagers in 1990 (see Figure 9).

FINANCIAL ANALYSIS OF CT-2 AND PCN OPERATIONS

By applying our market potential estimates to a range of metropolitan markets and combining the results with information on likely pricing levels and capital costs, EMCI has determined the economics of CT-2 operations. This analysis assumes the operation of one CT-2 carrier and omits the impact of roaming. To provide a benchmark for analysis, these results are compared to typical cellular operations. EMCI has examined viability for top 20, top 50, and top 100 metropolitan markets. A net present value (NPV) cash flow per pop (population in the market area) is used as the base for comparison. The NPV for CT-2 is based on a 20% discount rate to account for the relatively greater risk inherent in new technology ventures. Cellular is assessed with a lower level of risk, and a 15% discount rate is used.

In the largest markets, if CT-2 is able to achieve 3.6% penetration by the fifth year of operations (EMCI's high market potential), CT-2 will generate cash flow similar to cellular on a per carrier basis. This is likely an optimistic scenario for several reasons.

The Aggregate Mobile Communications Marketplace Number of Subs by Product

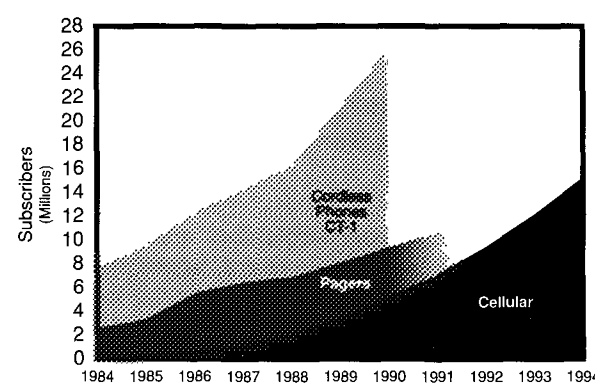

Figure 9

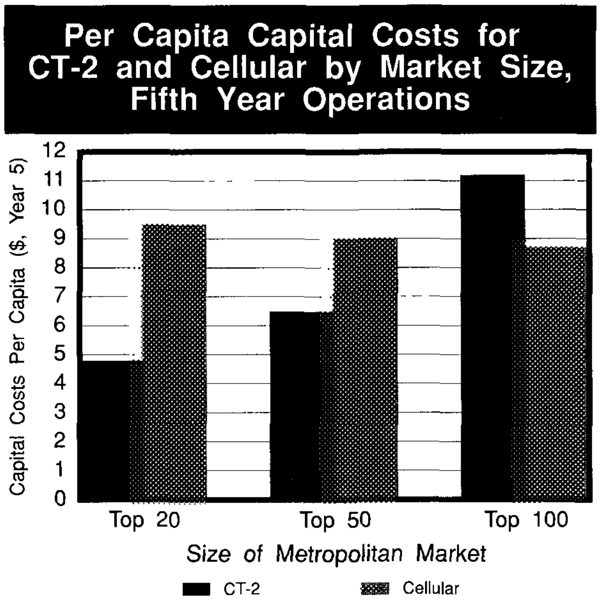

Figure 10

- CT-2 is likely to compete with cellular for some of its subscriber base, reducing its market potential.
- The introduction of PCN services will further erode CT-2's subscriber base.
- The CT-2 system is unlikely to provide coverage convenient for the entire market population. Achieving 3.6% penetration only on covered pops will reduce the subscriber base.

High and mid penetration scenarios present viable business opportunities while the low penetration scenario (approximately 1.2% penetration after five years) represents approximately a break even cash flow business. If CT-2 achieves lower penetration rates, CT-2 is not viable.

EMCI projects both CT-2 and PCN to have lower operating margins than cellular due to the following factors:

- lower revenue per subscriber relative to fixed costs such as management, accounting, and billing;
- significant expenditures to maintain the large number of microcells;
- relatively high interconnection costs which may or may not be directly passed on to the consumer; and
- significant marketing expenses although much lower than cellular on a per subscriber basis.

Under high penetration assumptions, CT-2 will achieve a better than 50% operating margin by the fifth year of operations, somewhat below cellular's average. Because the infrastructure necessary for a viable system cannot be reduced with lower market penetration, operating margins decline as projected penetration declines. This is primarily due to the fact that the number of initial cell sites is high and fixed for coverage purposes unlike cellular where a large area can be covered with a few cells. This affects capital expenditures, technical support and maintenance, and general and administrative expenses. Capital expenditures, in particular, do not decline linearly with market size. While cellular has a relatively constant capital cost per capita over a wide range of market sizes, initial CT-2 capital costs per capita are expected to increase dramatically with smaller markets (see Figure 10).

This analysis indicates that CT-2 may be a viable business even under moderate penetration projections in the largest markets. This result is sensitive to:

- the entry and number of PCN service providers;
- the number of CT-2 service providers; and
- the reaction of cellular service providers to the introduction of CT-2 service.

The variance around these projections increases as the market size decreases. Low population densities present in many metropolitan markets 50-100 will prevent viable CT-2 operations due to excessive capital costs.

PCN services will be differentiated from CT-2 by the ability to offer cell handoffs and full two-way calling capability (send and receive calls). These characteristics require PCN handsets and base stations to have greater technical sophistication than their CT-2 counterparts.

Initial cost estimates for PCN handsets are around $800, but costs are expected to decrease to approximately $300 when mass production becomes possible. This cost would be greater than a CT-2 handset if CT-2 could be mass produced. In the

U.K., CT-2 handsets are available for about $400, but the low demand for this product has precluded its mass production. In comparison to cellular telephones, PCN handsets will be lower cost, weight, and size. EMCI's consumer research indicates that it is important for PCN handsets to be less expensive and smaller than comparable cellular handsets to fulfill its market potential.

PCN and cellular service providers face similar costs. Both must install infrastructure, establish billing systems, and pay interconnect charges. Even though PCN, in theory, can bypass the landline public switched telephone network (PSTN) and switch calls, it must interconnect to the PSTN to access landline telephones and other networks such as cellular and private radio networks. Interconnect fees will be a major variable cost that PCN operators face.

For interconnection, local exchange companies (LECs) charge four to six cents per minute. PCN operators, like cellular operators, will pass this cost through to their customers. But since PCN operators will charge less for service than cellular operators, interconnect fees will represent a higher portion of their costs. A minute of cellular airtime usage costs about 50 cents. For the same minute on a PCN network, a user will only have to pay 25 cents. Thus, as a proportion of revenue, the interconnect charge is 10% for cellular and 20% for PCN. This indicates a lower profit margin for PCN.

Currently available CT-2 base stations cost between $3,000 and $7,000. PCN base stations with their greater complexity will be several times more expensive. They will, however, be closer in price to CT-2 base stations than to cellular cell sites which have a macrocell configuration and cost between $300,000 and $500,000.

As with CT-2, capital expenditures for PCN will not decline linearly with market size. PCN, like CT-2, requires a large number of installed microcells to adequately provide coverage. In the U.K., estimates for PCN network costs range from $1 to $2.5 billion per operator. The midpoint estimate represents an expenditure of $30 per capita per operator. Assuming half the total amount is spent by year 5, capital expenditures still total $15 per capita per operator. This compares to $4 to $12 per capita for CT-2 and $8 to $10 per capita for cellular (see Figure 10).

These prices are not strictly analogous since U.K. PCN costs are compared to U.S. CT-2 and cellular costs. In the U.K., Racal, one of the cellular operators, has spent approximately $14 per capita to date. For CT-2, OFTEL estimated capital expenditures of $100 to $200 million per operator, or about $5 per capita per operator. Ferranti, up through November 1990, had spent approximately $22 million. PCN operators in the U.K., then, have indicated that they will spend more than local cellular and CT-2 operators to implement service. The U.K. implementation of PCN is based on GSM, which is also their digital cellular standard. The U.S. implementation of PCN will likely differ and have substantially different cost characteristics. Whatever the final technology used, clearly, the number of base stations required will result in tremendous costs for the base stations themselves and the connecting network. As discussed above, the availability of existing cable networks, particularly those using the star topology may result in substantial savings for PCN implementation.

CONCLUSION

The concept and structure of PCN continues to evolve. Until the FCC announces a regulatory environment and the industry selects standards, operational characteristics cannot be determined with accuracy. Based on an understanding of existing mobile technology products, the requirements of a microcell technology, and the structure of cable networks, the following points are clear:

- If priced appropriately (at least 25%-50% below cellular for PCN and CT-2), PCN services can realize a large market, possibly several times the size of the existing cellular marketplace.
- The capital expenditures for PCN will be greater than that of cellular.
- Existing cable networks may significantly offset the costs of implementing PCN.

Because of the rapid evolution of the communications marketplace, those MSOs which move quickly to explore the synergies of cable and PCN will be best-positioned to meet the industry's needs when commercial operations begin in the mid-1990s. ■ *ADR.*

ABOUT THE AUTHORS

ARCHER S. TAYLOR, P.E., is a Principal and co-founder of Malarkey-Taylor Associates and its Senior Vice President, Engineering. He is also honored as a founder and pioneer in the field of cable television, having shared in building the first cable television system in the State of Montana in 1953.

Mr. Taylor has maintained a professional practice as a consulting engineer for the broadcast and cable industries since 1944. He is a Fellow and Life Member of IEEE, a Fellow Member of SCTE (UK), and a Senior Member of SCTE (USA). He is a graduate of Antioch College, with a B.S. in Physics.

He has served on the boards of the National Cable Television Association (NCTA), the Cable Television Advisory Committee (CTAC), and the Broadcast, Cable, and Consumer Electronics Society of the Institute of Electrical and Electronics Engineers (IEEE).

He has written a monthly column published in *CED* magazine on a variety of mostly technical issues since 1985. He has published articles in many other journals including IEEE and the NCTA Technical Papers.

ANDREW D. ROSCOE, is President and founder of Economic and Management Consultants International, Inc. (EMCI). He has consulted to the communications industry since 1982 on projects including cellular and paging competitive environment analysis, development of financial and business plans, and demand potential projections.

Mr. Roscoe is a leader in research on the potential for PCN and other microcell technologies. Recent projects have included FCC filings for PCN experimental license holders, consumer surveys, and market demand projections. He has interviewed extensively microcell manufacturers and service providers in the U.K.

Mr. Roscoe has published a number of studies on communications technologies and services in the U.S. and abroad. As a leading consultant to the mobile communications industry, he is frequently quoted in the popular, financial, and trade press and often speaks at industry trade shows. Mr. Roscoe holds a Master of Arts Degree in Economics from the George Washington University.

REFERENCES

Cox, Donald C.; *Universal Digital Portable Radio Communications*; Proc IEEE; April 1987; pp 436-477. (Dr. Cox is Division Manager of Radio Research at Bellcore).

Steele, Raymond; *The Cellular Environment of Lightweight Handheld Portables*; IEEE Communications Magazine; July 1989; pp 20-29. (Dr. Steele is Professor of Communications at the University of Southampton, England. In 1986, he formed Multiple Access Communications, a company concerned with digital mobile radio systems).

Cox, Donald C.; *Portable Digital Radio Communications - An Approach to Tetherless Access*; IEEE Communications Magazine; July 1989; pp 30-40.

Matsuo, Naoki; *Personal Telephone Services Using IC-Cards*; IEEE Communications Magazine; July 1989; pp 41-48.

Steele, Raymond; *Deploying Personal Communications Networks'* IEEE Communications Magazine; September 1990; pp 12-15.

Cox, Donald C; *Personal Communications - A Viewpoint*; IEEE Communications Magazine; November, 1990; pp 8-20.

EMCI; *The Market for CT-2*; proprietary report; copyright September, 1990.

EMCI; *European Cellular Market*; Vol I and II; proprietary report; copyright September 1990.

Federal Communications Commission; *Notice of Inquiry*; GEN Docket No. 90-314; June 28, 1990.