

Wireline-based Communication Access Technologies in Rural Kentucky

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Wireline-based Communication Access Technologies in Rural Kentucky

Executive Summary

In less than a decade, access to the Internet has become a critical measure of the development level of communities and firms. Similarly, residential access to the Internet is an important element of the quality of life for households. Recent studies that examine the existence and extent of the digital divide between those who are connected and those who are not point out that a significant number of U.S. households are still without Internet access. In many cases the lack of access reflects either inadequate income to afford a computer and connection charges, or a decision by individuals that they do not require a connection to the Internet. However, for other people their lack of connection reflects inadequate infrastructure – they simply cannot connect at reasonable cost and/or at a minimum service quality level through their telephone system or other means to an Internet service provider.

While the focus to date has been upon the relatively small number of individuals who live in areas where service is not available there is a larger but less recognized issue. The critical issue is rapidly becoming not whether one has access but the quality of that access – what is the maximum transmission speed that can be reliably achieved. As the complexity and volume of information that is routinely transmitted over the Internet increases from year to year, it is no longer sufficient to simply have a connection, but to have a high-speed connection. If the digital divide is defined in terms of those with or without high-speed access then the problem is far more pervasive.

A critical issue of connectivity is what is termed “last mile” access. It is that connection from the customer to a high-speed communications network. Frequently, this connection is narrow band analog (voice band modem); effectively a bottleneck in the transmission of data from and to a much faster upstream digital network. In recent years, Kentucky has made notable strides in increasing access to the Internet and high-speed last mile digital connections are available in every county, but this is not the same as saying that these connections are available in all parts of a county, nor that they are particularly affordable for residential or small business use. Indeed, every county in Kentucky has a connection to some form of high-speed access. The Kentucky Information Highway (KIH) connects all counties, but it is primarily a service for government and public sector agencies like schools and libraries. Not only are private businesses unable to use this connection path, but residential customers are also unable to obtain any direct benefit from a county’s KIH node.

This report focuses on wire-based access through the public telephone system in part because it is the means by which most people currently connect to the Internet, and because it appears to be the means with the greatest potential to provide near-term future high-speed access to those who are currently on the wrong side of the digital divide. While cable systems and wireless methods are clearly emerging as alternatives to telephone wire-based approaches, they are not options now in much of the state because the underlying infrastructure is not available and is unlikely to become available soon.

Several related elements dictate the type of access that is available in a given area of Kentucky. The most important is the functionality of the central office switch that serves the customer and what other equipment may be housed in the central office location. While virtually all switches in Kentucky have the capacity to host high-speed Internet access, many are not currently programmed to do so. In some instances this is not a real constraint because this service can be provided to a customer remotely through another switch that is linked to the local switch (Figure 1). Every county has at least one switch and most switches are located in the larger cities in a county.

The second main element affecting access is the customer's distance from the switch. While some technologies, notably ISDN, are relatively distance insensitive, others, such as the increasingly popular xDSL technologies, are limited by distance. xDSL technologies are generally only available within a less than three mile radius of a central office. Figure 2 and Figure 3 show the footprints of actual ISDN and xDSL coverage (as of July 1, 2000 and January 19, 2001) as well as *potential* xDSL coverage as though the technology were available at every central office in the state. Once again it is clear that the highest actual level of connectivity occurs in more urban areas, especially in the metropolitan counties and in the cities in the nonmetropolitan counties. xDSL technology is especially important to the business community because cable modems, the current best alternative, often cannot support business traffic demands due to capacity limitations.

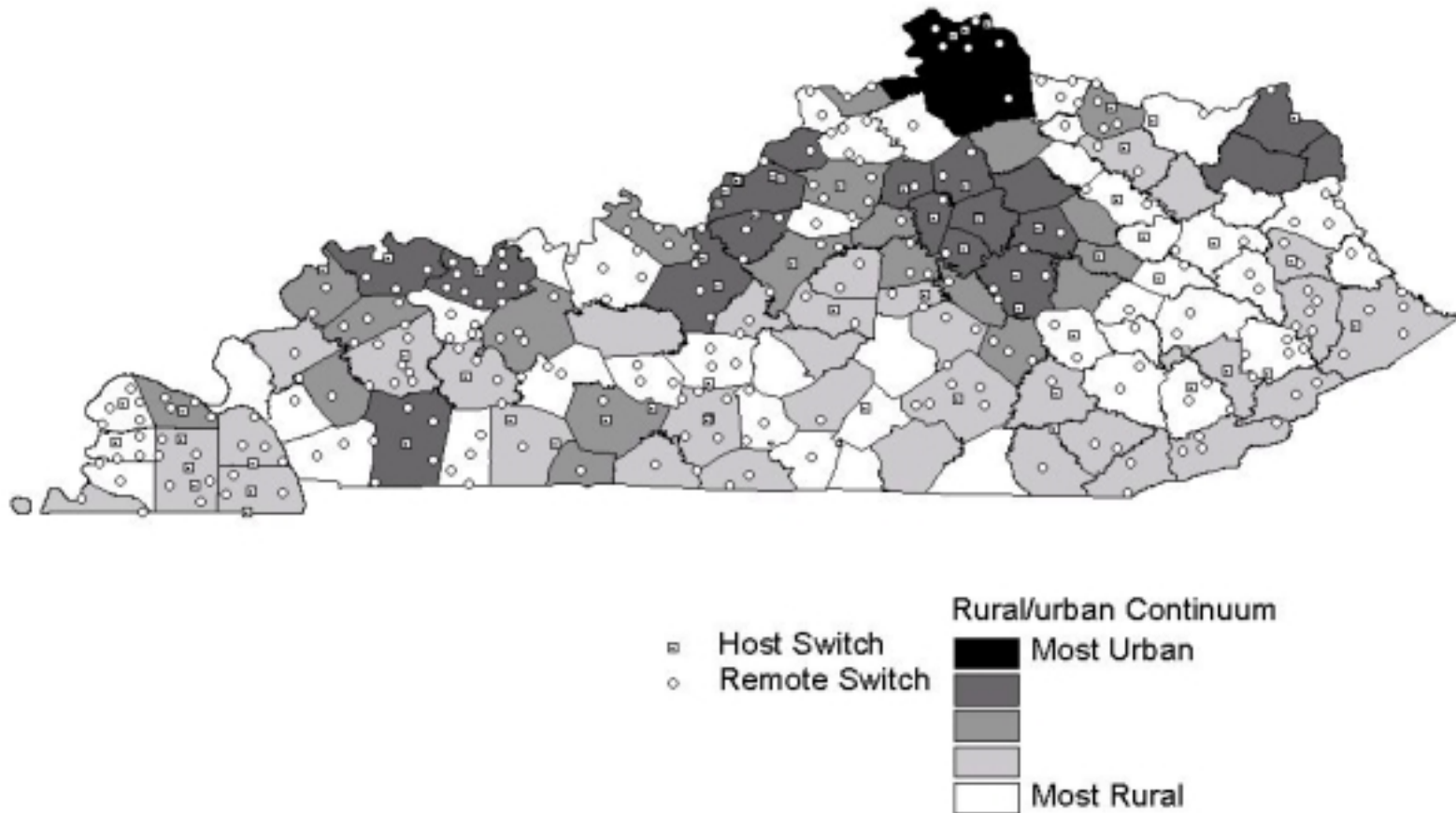
In practice, the radius of high-speed connectivity is significantly less than three miles because telephone poles and wires follow road grids and because of significant noise and other signal quality problems in the subscriber lines. However, the effective range of xDSL can be extended by the practice of locating a portion of the necessary technology outside the central office, as is already done to extend regular telephone service to more distant areas. Remote Digital Subscriber Line Access Multiplexers (DSLAMs) aggregate individual xDSL lines and connect them at high bandwidth to a service providers' network. Installing a remote DSLAM effectively establishes a new radius of connectivity that can be stepped out a significant distance from the associated switch and central office.

This leads to the final and perhaps most intractable problem. While the unit cost of providing high-speed access continues to fall, it remains a technology with high capital costs and significant scale economies (i.e. price falls as volume of use increases). While it may be possible using remote DSLAMs or other means, to provide high-speed Internet access in most of the state, the reality is these investments will only be made in areas where the level of customer demand is high enough to justify the capital outlay. This suggests that two things will be central in determining the ongoing deployment path of high-speed access – population density and income levels. Population density is important because it allows people to be connected with less infrastructure investment and, because high population densities are generally associated with large numbers of people, the number of users is more likely to be sufficient enough to meet minimum levels of demand. Income levels are important because high-speed access requires a significant investment to establish the connection (cabling, modem and computer) and ongoing monthly outlays to maintain the connection and for an Internet service provider.

It is clear that full participation in the new economy and the emerging global society requires high-speed Internet access. Previous discussions of the digital divide have sidestepped this issue because they have only examined where Internet access was possible and not the speed of the access. It is already clear that voice band modems, the current dominant technology, cannot deliver sufficient bandwidth to meet existing levels of data flow over the web. Change has now accelerated to the point that voice band modems provide little better access to the full spectrum of information available in our society than do traditional print and broadcast media. This has clear implications for economic development. Those places without access will find it increasingly difficult to compete in the modern economy. Further they are likely to be increasingly undesirable as locations for people to reside. Much of the power of the Internet derives from its role as both a business tool and a consumer good. Those cities that already host a central office and switch have the greatest opportunity to tap this power and use it to enhance their growth. Conversely, places currently lacking access will have only a short window of opportunity to catch up to the current standards before they lose sufficient income and population to eliminate the chance of ever being connected.

Figure 1

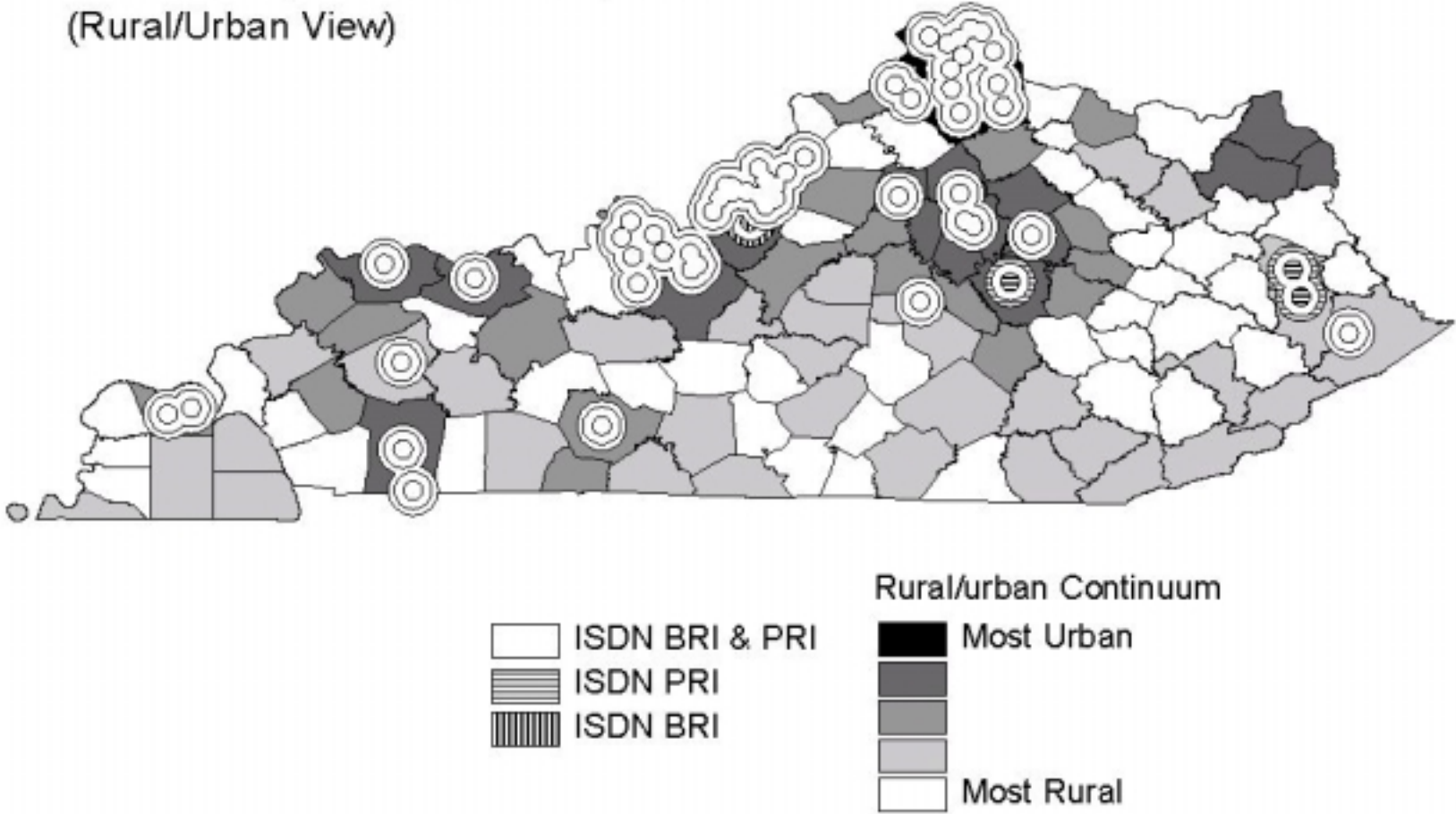
Kentucky Host and Remote Switching



Source: Data from LERG, July 1, 2000.

Figure 2

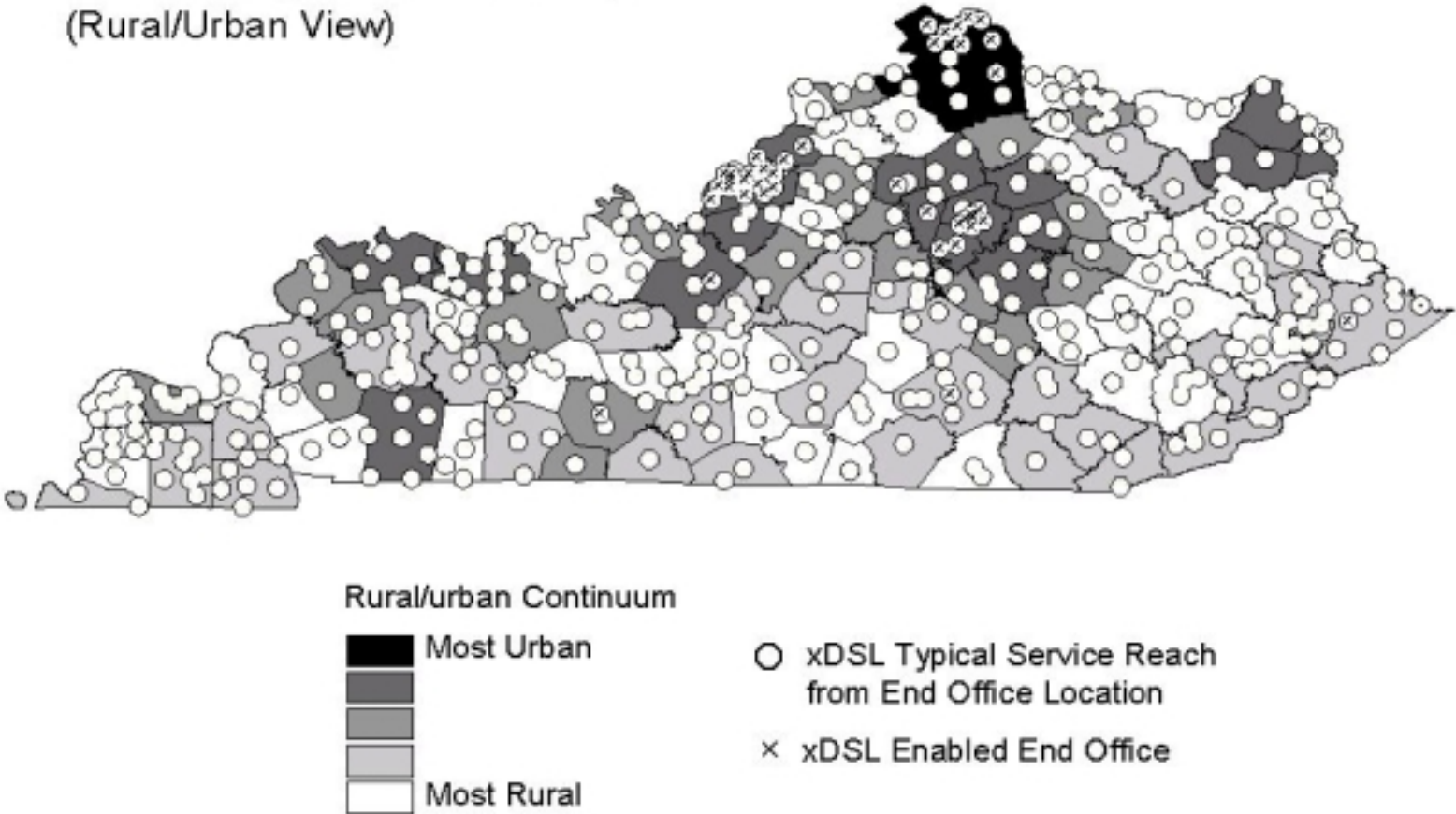
Kentucky ISDN Footprint (Rural/Urban View)



Source: Data from LERG, July 1, 2000.

Figure 3

Kentucky xDSL Footprint (Rural/Urban View)



Source: Data from LERG, July 1, 2000 and TelcoExchange, Jan. 19, 2001.

Wireline-based Communication Access Technologies in Rural Kentucky

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Rural and remote communities can employ high-speed digital communications and Internet services to help overcome their traditional distance penalty.

Introduction

The volume and usefulness of content available on the worldwide Web is growing continuously as is the capability of the Internet. Many businesses have enthusiastically seized the medium as a means to identify and reach customers previously inaccessible, to provide a variety of new electronic services, and to reduce the cost of intra- and inter-business transactions. State and local governments too, while perhaps less quick to respond, are beginning to implement many routine government services electronically. Indeed, one of the major benefits of e-commerce, e-government, and better communication penetration generally, is the ability to bring people, businesses, and communities closer together. As a principle effect, the virtual compression of space afforded by high-speed communication services is seen as a means for rural and remote communities to overcome their traditional distance penalty (Parker). Consequently, the availability and adoption of these communication technologies is frequently viewed as a necessary step toward community economic revitalization (Grimes).

One assumption underlying the success of this communication revolution is that most individuals and organizations are in fact connected, and that their access is of sufficient quality. Access to the telephone network is often considered as a sufficient proxy for ability to access the Internet. However, it is increasingly clear that having a telephone is not the same as having full connectivity. Today, the measure of quality access rests on digital transmission capability, broadband high bit rate, low error rate, and near dedicated service (Malecki "Digital"). However, many communities and individuals, particularly, but not exclusively, in rural areas, are encountering numerous obstacles in achieving the so-called 'last mile' connection from customer premises to communication network at a service level that makes full use of the Internet's capabilities.

A recent national inquiry into the 'digital divide', the extent of people's exclusion from advances in digital technology and of adequate quality of service, finds 'rurality' to be negatively related to the likelihood of households having electronic access, even when income is held constant (U.S. Department of Commerce). This finding is naturally cause for concern in a predominantly rural state such as Kentucky. Several recent studies help frame the situation at the state level. Estimates for 1998 show that 21.5 percent of all Kentucky households were connected to the Internet (26 percent nationally), which represents approximately 59 percent of computer owning households (Bohland). Encouragingly, the same study also found that the difference between connectivity in metro

Bandwidth refers to how fast data can be transmitted and is expressed in bits per second in digital systems (Norton).

Broadband is defined by the FCC as the capability of supporting both up- and downstream transmission rates of at least 200Kbps from the consumer's connection to the network (USDA). A widely accepted but much less rigorous standard defines broadband as any transmission rate in excess of 56Kbps.

Consider an illustration of transmission speed differences: the size of this report file is about 4.8MB or 5 million bytes. It would take approximately 3 minutes to transfer at 200 Kbps but nearly 23 minutes at 28.8 Kbps, the common speed of many voice band modems. In contrast, broadband transmission of 1.54Mbps would transfer the file in only 25 seconds

and nonmetro areas is small: approximately 64 percent compared with 58 percent. The estimates, unfortunately, do not differentiate connectivity in terms of broadband capability nor by the last-mile facility used, foreexample, cable modem, wireline technology, wireless, etc. A second study, however, estimates that household broadband penetration in Kentucky, both via cable and wireline, is less than 10 percent (Smolenski). In addition, nationally the probability of broadband service from any source tends to decline with population density, less populated areas are the last to receive such service, and access is related more to last-mile connectivity rather than access to fiber optic backbone networks. In fact, a recent Kentucky state survey of regional Bell operating companies found that only Louisville and Lexington are able to receive newer wireline-based broadband services (U.S. Department of Agriculture).¹

These figures seem to indicate that rural areas and communities in Kentucky may still be facing a distance penalty inhibiting their access to advanced communication technologies relative to more densely populated urban places. Clearly, efforts to identify the scope and potential of existing infrastructure to provide last-mile broadband connectivity across Kentucky are justified.

This document provides a brief overview of Kentucky's telecommunications infrastructure particularly in terms of how it is projected into rural areas and provides a comparison of the primary means of broadband access over the wireline plant of the public switched telephone network (PSTN). The wireline infrastructure of the PSTN is one of the most heavily used of the four main categories of access technologies (the others being cable, wireless, and fiber). 'Access' here refers to the last-mile connectivity challenge from the point of view of residential and small business customers rather than of ISPs to upstream networks. The customers' concern is how to connect to the network of their ISP and onto the Internet, or for gaining remote access to their local area network (LAN). This report examines three categories of wireline access solutions: voice band modems (VBM), integrated services digital network (ISDN), and digital subscriber line access technologies (xDSL).² Where possible, a deployment inventory for Kentucky is provided, accompanied by a description of infrastructure requirements and obstacles.

¹ The survey apparently did not include wireline-based broadband service offered by competitive local exchange carriers (CLECs) or Internet service providers (ISPs).

² Leased private line services such as T1 and frame relay represent another wireline access solution.. While frequently more costly, these solutions provide a high degree of reliability, security, and service often not available from other sources (Boardman). Private lines of this type are typically used by larger business for their network access needs but are generally less appropriate for the needs of residential and small business customers.



Outside feeder plant enters the CO in the cable vault.

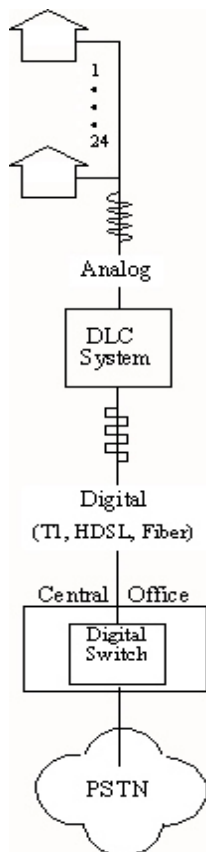
PSTN: Structure and Projection into Rural Areas

The PSTN is the most ubiquitous communication infrastructure in the nation. National telephone penetration stands at 94.1 percent and in Kentucky at 92.9 percent (U.S. Department of Agriculture). The use of this infrastructure for data transmission has already surpassed telephone traffic volume. At the same time, demand has increased for affordable yet faster wireline data access technologies that allow greater use of the Internet's rich graphical interface, video and gaming activities, and time sensitive business information.

Given that the PSTN reaches nearly every household, and that it is a familiar technology increasingly used for data transmission, it will likely emerge as a primary access route in both urban and rural places, particularly if they are outside areas having upgraded cable television plant. However, the capacity for widespread access via the PSTN rests not only on the development and/or deployment of access technologies, but also on the spatial characteristics and digital capabilities of the existing infrastructure.

Three elements are important in understanding the capacity of the PSTN to provide last mile connectivity and advanced communication services. These include the condition of subscriber access lines, the capability of central office switches, and distance from the customer to the switch (Malecki "Digital").

DLC Based POTS Deployment



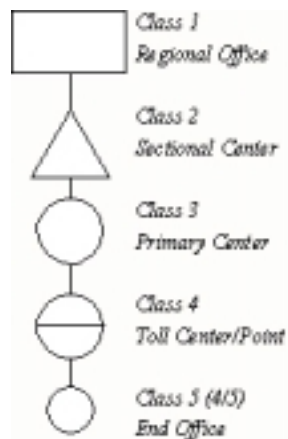
Subscriber Access

Subscriber access lines are the pair of copper wires that extend from the local access provider's switching equipment to the customer's premises over which 'plain old telephone service' (POTS) is provided. They are also sometimes referred to as the copper loop, local loop, twisted pair, or outside plant. Subscriber access lines are always analog unless digital lines and service are specially ordered. The loop may be constructed of different thicknesses of wire (normally 26- or 24-gauge) and may include line equipment such as repeaters, repeater coils, or loading coils that help maintain the performance of analog voice frequency transmissions over distance and in the presence of bridge taps. The average length of a subscriber access line is about 18,000 feet but is frequently longer, particularly in rural areas (Rowley). The length of the subscriber line is frequently important in determining what kinds of telecommunication technologies and service level are available to consumers. In the United States, 18,000 feet provides reach to approximately 80 percent of subscribers (ADSL forum). Groups of access lines from multiple customers converge into what is sometimes termed the feeder plant, which then goes on to the local exchange carrier's (LEC) central office (CO). The CO, or switching center, is a building that houses telephone switching equipment and other telecommunications hardware.

Subscriber lines are not necessarily individually connected to the CO but may first be aggregated using a digital loop carrier (DLC), particularly when the subscriber is more than 3.5 miles from the CO. In this system, subscriber lines meet at the DLC where their analog voice signals are

Multiplexing is a general reference to techniques that allow more than one signal to pass over a single communications channel at the same time. Both analog and digital signals can be multiplexed. Time division multiplexing is one method where small pieces of multiple digital signals are interleaved one after another, rapidly transmitted, and reassembled at the terminating end. Pair gain, likewise, is a reference to the multiplexing of several voice conversations over fewer transport lines (Newton). Multiplexing employed in the DLC should not be confused with packet transmission since the circuit path is predetermined and the order that the individual pieces of the signal arrive is critical to their re-assembly.

Switching System Hierarchy



rapidly and repeatedly sampled and converted to a digital signal. Individual lines are then multiplexed and transported on to the CO, frequently over fiber optic cable, T1 lines, or other high-speed transmission medium. One advantage of a DLC system is that a digital signal can be easily and exactly regenerated over distance whereas repeated analog signals suffer from increased background noise. A second important advantage is that DLCs are a means of enabling a CO to serve more remote customers and new customers at reduced cost since electronics are now being substituted for extensive physical copper loop (IEC “Digital”). DLCs are frequently used to extend POTS and other advanced telephony services to new suburban developments, business parks, and less populated rural areas, for example.

Switching Hierarchy

Each CO has at least one powerful mainframe computer, that acts as a circuit switch, which receives and routes calls to their final destination. Note that from the CO switch and on through the PSTN, all transmissions are digital. In the PSTN pure hierarchy of switching systems, switches are classified 1 through 5 as to their position in the network routing pattern that ensures complete interconnection of all locations (IEC “Fundamentals”). Class 5 and Class 4/5 switches (also called ‘end offices’) are those directly tied to the subscriber access lines and customers of the local exchange. When a call is placed, a circuit path is created, originating from the Class 5 office and passed on to a Class 4 office, the first point of aggregation for network traffic. Class 4 offices are termed toll centers or points, depending on the type of operator assistance that is provided for call completion. Higher level switching centers generally correspond to larger and larger geographic regions and have as their subscribers lower level centers. Class 1 offices correspond to one of ten regional centers in the United States, while Class 2 (sectional center) and Class 3 (primary center) offices are subdivisions of the more aggregated (e.g. larger) entities. Outbound calls from one local exchange ‘climb’ this network ladder to the level of CO required to connect to the destination local exchange. CO switches are linked to each other with high capacity trunk lines, completing the network. Class 4 to 1 offices are also generically called tandem switches since they provide trunk to trunk, rather than trunk to subscriber, connections.

This basic hierarchy of the circuit switching fabric continues to undergo various modifications in response to competitive pressures, demands of data traffic, and the improvement and provision of new advanced telecommunication services.

For example, basic signaling and information service advances have contributed to a high-speed data packet switched network overlay to the PSTN (but separate from public packet switched networks). The first was the development in the mid-1970s of an out-of-band signaling network, known as common channel signaling or common channel interoffice signaling (CCIS). Highly sophisticated multi-layered messaging software, known as Signaling System 7 (SS7), installed at the end office switch or provisioned by a host switch, sends a request to a signal control

point (SCP) when a subscriber makes a phone call. The SCP, a remote computer, in turn determines the exact path through which the call should be routed and verifies that the terminating end is not occupied. Only then are the trunk lines seized, the circuit established, and the call placed. This interoffice messaging is routed through a network of high-speed packet switches called signaling transfer points (STP). There are nine such STPs in Kentucky.

Packet-switched describes a type of network in which relatively small units of data, packets, are routed through the network based on the destination address contained in the header of each packet. Individual packets may travel by different routes through the network to their destination. Packet communication allows the same data path to be shared among many users in the network and is said to be connectionless (Newton).

One significant advantage of packet switched out-of-band signaling is to improve the efficiency of trunk line use since unnecessary path setup is avoided. It also enables faster call set-up and tear down, and various services such as call waiting, caller identification and screening, 800 number routing, and automated credit card calling. SS7 also serves as the network protocol needed for integrated services digital network (ISDN) functions and serves as the messaging trigger for advanced intelligent network (AIN) call processing (IEC "Signaling"). AIN provides for more advanced database query functions and call routing options including voice response services, enhanced and selective call forwarding, enhanced billing, and support services for mobile communication devices.

The SS7 and packet-switched signaling overlay is extremely important for the provision of reliable, cost efficient voice and data communication services over the PSTN. The demands placed on the SS7 network are likely to expand as database querying functions become more sophisticated and interactive, and as CLECs make greater use of the service to manage and optimize their use of switching and trunk facilities (IEC "Competitive").

The strict hierarchy of the PSTN has started to blur somewhat as a result of new competitive pressures. For example, the activities of multiple long distance providers has contributed to a network overlay that in many cases bypasses some of the traditional intermediary switching steps. And behind the PSTN lies growing public and private (shared) packet data networks using high-speed transmission technologies and protocols such as X.25, asynchronous transfer mode (ATM), or frame relay. These packet networks, whether operating as a wide area network (WAN) or as backbone transmission lines, are and will be increasingly important in the provision of the kinds of advanced telecommunications and Internet services customers currently expect and will demand in the future. Indeed, the development of Voice over Internet Protocol (VoIP) telephony promises to dramatically change the way that circuit- and packet-switched networks are jointly managed and interconnected (IEC "Signaling").



Voice over Internet Protocol (VoIP) test phone. Each phone has a unique Internet address.

Many of these developments are expected to place further demands on switching systems and expand and intensify the role of the CO. This is because the CO and the distribution of end offices is what still matters for connectivity since they are the focal point of subscriber access lines. Switching equipment and CO construction, however, is expensive; even more so in terms of opportunity cost when population density and, hence,

demand drops, as in rural areas. To provide services to these areas as cost effectively as possible, local exchange providers have leveraged or scaled existing resources in the form of host-remote switching.

Host-Remote Switching

Host-remote switching has been used in the infrastructure expansion of the PSTN to provide advanced telephony services while controlling for cost, both in rural and urban places. In this sense, remote switches can be thought of as powerful remote aggregators that are dependent on a host switch for common processing functionality, typically for originating and terminating traffic access.

Remote technologies such as host switching and DLC systems are cost effective means of bringing advanced telecommunications functionality of urban areas to more remote places.

The incidence of host-remote switching is of interest because the remote generally serves as an end office; that office to which access lines and DLC systems are connected. In Kentucky, there are 75 hosts providing additional functionality to other switches.³ Some 27 (36 percent) are located in metro counties compared with 48 (64 percent) in nonmetro counties. Remote switches in the state total 268; clearly a host can provide functionality to more than one remote. There are 41 (15 percent) remote switches in metro counties with the vast majority, 227 (85 percent), serving nonmetro counties.

The geographic distribution of host-remote switching entities is presented in Figure 1, overlaid with the rural-urban continuum classification of Kentucky counties in 1993.⁴ The dispersion pattern of remote switches is fairly even across the state, and, according to the LERG, 255 (95 percent) are designated Class 4/5 end offices. In fact, just over half (57 percent) of all end offices statewide are remote offices.

Voice Band Modem (VBM)

The most widely deployed connectivity technology is dial-up voice band modems (VBM), generally installed as standard equipment in most home computing packages (U.S. Department of Agriculture). These modems convert the digital signal from a computer into analog form so it can pass over the subscriber's access line. Combinations of various modulation techniques are used to compress the data and achieve higher transfer rates. VBM transmission speed is subject to an upper limit imposed by the inherent architecture of the PSTN that was designed to provide quality voice service. Filtering devices (load coils, etc.) constrain bandwidth to a limited range and digital sampling devices in DLCs operate at a maximum of 64Kbps (IEC "Digital"). Other characteristics

³ Information on switching systems in Kentucky was obtained from the Local Exchange Routing Guide (LERG) compiled by Telcordia Technologies. The LERG provides information about the location, ownership, and functionality of every individual PSTN switch in the United States. The data set released for July 1, 2000 was used for this report.

⁴ The rural-urban continuum is based on county population and proximity to metropolitan areas. These codes also form the basis for the metro/nonmetro distinction used in this paper. Specific details can be found at <<http://www.ers.usda.gov/epubs/other/typolog/typ89ky.txt>>.

of the analog line, such as the signal-to-noise ratio, also place limits on transmission rates.

Today’s most advanced VBM’s transmit data asymmetrically, meaning that the downstream rate to the customer is faster than the transmission upstream. This in itself is generally no particular handicap since most end users consume more data than they generate. Most modems are also rate adaptive, sacrificing speed to maintain reliable transmission over long distance and if line conditions are poor. Maximum transmission rates for two dial-up modem standards are as follows, with more common realizable transmission rates in parentheses:

Table 1: VBM Transmission Rates

Modem Standard	Bit Rate Downstream	Bit Rate Upstream
V.34	34 (28) Kbps	34 (28) Kbps
V.90	53 (45) Kbps	34 (34) Kbps

Source: U.S. Department of Agriculture.

Within the PSTN switching structure, dial-up modem calls are treated just as any other call, that is, they are circuit-switched. Thus, while transmission rates are nowhere near what is considered broadband, VBM achievement and success rests on the fact that they can provide an immediate connection almost everywhere a telephone line exists (ADSL forum).

ISDN Technologies

Integrated services digital network is a second network access technology that operates over standard copper subscriber access lines. It requires, however, that the CO be upgraded with ISDN software and signaling equipment. Services are ‘integrated’ because they can support a variety of applications at the same time, both voice and data, whereas VBM technologies can support only one. Since ISDN is digital from end to end, it provides much higher transmission rates. ISDN is also primarily a circuit-switched service that establishes a physical link between points, just like POTS. However, some control features are packet-switched and other channels can be set up to do so as well. The service area of ISDN can be extended out approximately nine miles from the CO with the use of ISDN repeaters and has the advantage of being able to operate through most DLCs (Newton and EIC “Digital).

Two levels of service characterize ISDN (Eicon). Basic Rate Interface (BRI) is normally delivered over a single twisted pair (a U-interface) and consists of two 64 Kbps bi-directional bearer (B) channels (144 Kbps if combined) and one 16 Kbps data (D) channel and is sometimes simply referred to as 2B+D. B channels carry customer voice and data signals and may be shared among several devices (up to eight) such as a fax, phone, or PC. These channels are ‘clear’ in that no bandwidth is reserved for signaling. Signaling for call setup, tear down, and the provision of other administrative and functional services such as caller identification is provided by the D-channel which is packet switched. D-channel

signaling is converted into SS7 signaling once it enters the carrier network. If a switching entity is not SS7 enabled, then signaling reverts to in-band, reducing available bandwidth on the B channel to 56 Kbps. ISDN BRI is considered an appropriate choice for the combined voice and data needs of residential and small enterprise customers.

Primary Rate Interface (PRI), consists of 23 B-channels and one 64 Kbps D-channel (23B+D) and is suitable for larger business and branch plant networking. ISDN PRI operates over two twisted pairs and, since it can provide transmission speeds up to 1.54 Mbps, can be thought of as 'enhanced' T-1 service (Newton). PRI service is frequently connected through a NT2 (Network Termination 2, which is essentially an on-premises PBX), which redistributes network resources locally. Otherwise, the two versions of ISDN are very similar.

ISDN functionality, like some other switching capabilities, can be provided locally from a remote host switch. These are identified in the LERG as a Foreign Serving Office. Other remote arrangements such as the Alternate Network Service Agreement (ANSA) used by Bell South provides ISDN service to a local CO from an adjacent enabled switch at no additional cost to the customer. As an illustration, Bell South ISDN BRI service in Kentucky is provided remotely in 31 percent of its enabled switches (data from <<http://bsonline.bellsouth.net/isdnvs/avail.html>>, January 04, 2001).

While primarily a circuit-switched and dial-up service like VBM, ISDN does and can support a variety of packet-switched capabilities. For example, in addition to its signaling function, the D-channel may be used with other packet-switched network protocols (e.g. X.25) to provide for functions such as credit card verification. B-channels can also be used for packet data transfer and connect into a X.25 or frame relay packet switched network. Packet-switching also allows ISDN to be configured to provide 'always on' capabilities, like what would be achieved using a leased dedicated line. These packet-switching functions, however, are not available everywhere.

ISDN is a relatively mature technology, and due to its integrated nature supports a wide variety of applications beyond simple Internet access (National ISDN Council). Some examples include remote LAN access and telecommuting; advanced telephone capabilities; credit card, automatic teller, and other banking services; and video conferencing applications. However, ISDN is somewhat more complicated to install and, because it requires external power sources on the customer premises, necessitates back up power sources or additional access lines to ensure that POTS is available in the event of power failure. This and generally higher up-front and service costs may explain in part the low adoption of ISDN by more casual users of advanced telecommunications services.

Kentucky ISDN Footprint

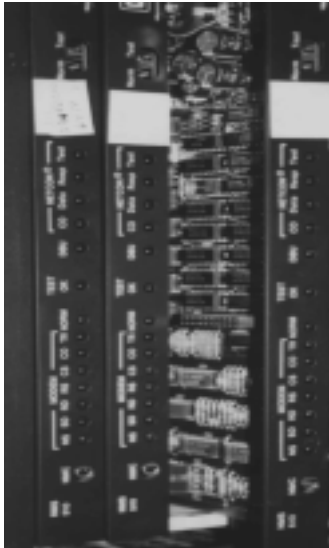
Since ISDN is a PSTN switching functionality, its presence on a switch-by-switch basis is recorded in the LERG. Figure 2 depicts the geographic distribution of both ISDN BRI and PRI service as of July 1, 2000, overlaid with the Kentucky rural-urban continuum by county.⁵ The coverage area is shown as a series of concentric circles; the first two at 18,000 and 36,000 foot intervals and the third at 48,000 feet which is

⁵ Switching functionality can change fairly rapidly. For example, recent Bell South data (January 04, 2000) indicate the presence of eighteen additional ISDN enabled switches since the publication of the July 1, 2000, LERG.

roughly the distance that ISDN can typically be served using repeaters on the access line. Map coding distinguishes between the two interfaces and where they coincide. In all but a few instances, both ISDN service levels are provided together and are mostly concentrated in the predominantly urban areas. LERG data reveal that a total of 75 CO switches in Kentucky are enabled with ISDN software and transmission electronics. The majority of switches, 52 (69 percent), are located in metro areas while 23 (31 percent) are classified as nonmetro, although several of the latter provide only the basic rate interface. As evident from this picture, ISDN has failed to become the sort of ubiquitous communications medium that some predicted it would be only 5 years ago.⁶

xDSL Technologies

A third transmission technology that utilizes the existing twisted copper infrastructure is known as a digital subscriber line. xDSL is a general reference to a family of digital, high-speed, point-to-point, network access technologies capable of carrying data, voice, and video transmissions. While initially intended to deliver video-on-demand, some variants are emerging as a cost effective residential and small business high-speed, last mile, Internet or remote LAN access solution.⁷



ADSL modem cards at the local end office.

There are at least six variants of xDSL in various stages of development and deployment and, in many cases, industry standards are not yet fully settled (Aber). In general, the basic operating premise is similar for all types. However, one important difference between variants is whether or not it has the ability to simultaneously carry high-speed data and POTS service. While not all variants are capable of this dual function, the following general description assumes that it is since this is the type of technology most relevant for residential and small business use. The subsequent section goes on to explicitly indicate which variants are POTS capable.

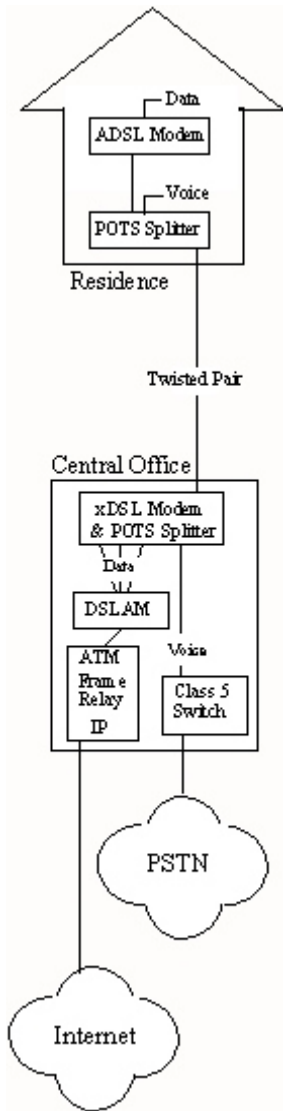
xDSL, like other access methods, use advanced modems located at the customer's premises and at the terminating end of the subscriber access line (i.e. the CO) to create high-speed data transmission channels. Unused frequencies above the 4Khz voice band are modulated using one of several different techniques depending on the xDSL variant to create a digital data channel. This is then divided using a channel splitter to create separate up and downstream channels. For normal residential and small business applications, a passive splitter in the modem or the network interface device draws off the low frequency signal that carries basic telephone service from the data signal. In an alternative configuration,

⁶ A distinction should be made, however, between the use of ISDN as a choice for remote LAN access, which is not uncommon in urban areas, versus the optimistic forecast that ISDN would eventually surpass modem-based communications. Today, dial up VBMs number in the millions while ISDN lines remain in the 100,000's (US Department of Agriculture; Eicon).

⁷ On-demand streaming applications of xDSL are still being actively pursued; for example, Blockbuster recently launched a 'movies-on-demand' service in selected cities (Kelly).

low-pass filters at the front end of voice devices, such as telephones, fax machines, and security alarm systems, protect them from the high frequency data signal. In either case, POTS and data service are provided over the same twisted pair but since the signal separation is passive, POTS will continue to function even if data service is interrupted or compromised (IEC “Internet”).

Typical xDSL with POTS Deployment



At the CO, voice transmissions are diverted to the teleco’s Class 5 switch and processed through the PSTN in the normal manner. Incoming data traffic from multiple xDSL lines are aggregated by a network device, a digital subscriber line access multiplexer (DSLAM), and connected to an ATM, Internet protocol (IP) or frame relay network, or more generically, a WAN. This data traffic is directed to the ISP that provides Internet service to the xDSL customers. While initially traveling over the wire line infrastructure of the PSTN, the xDSL data service is diverted to a packet-switched network and provides a constant, always on connection from the customer premises to the WAN and on to the Internet.

xDSL has several advantages over ISDN and other dial-up connections. One of the most significant is that xDSL can offer much higher bandwidth, depending on the particular variant (discussed below), and competes well against ISDN (and leased lines) in terms of price. Since xDSL is not circuit switched like ISDN, but rather in a dedicated network service, its has the advantage of avoiding call setup time and busy or no circuit signals resulting from increasing congestion on the public switched network. xDSL has the additional advantage of being powered over the twisted pair and so doesn’t need external and redundant power sources to operate and maintain ‘lifeline’ POTS. This feature alone reduces the initial setup complexities, compared to ISDN. Finally, unlike voice band modems, both xDSL and ISDN offer the convenience of simultaneous POTS and data service.

Once DSLAM equipment has been installed in the local CO, xDSL availability and performance is generally a function of four primary variables. These include the distance of the customer from the local CO, the quality of the local loop, equipment upgrades if service is to pass through a DLC, and the xDSL variant employed.

Distance, or the length of the local loop, matters because high frequency signal attenuation increases as the length of the copper wire increases. Signal loss raises error rates and reduces the level of reliable available bandwidth. Distance limitations differ for each xDSL variant ranging from 50,000 to 1,000 feet for a given standard transmission rate, with 18,000 feet being the most common maximum length.⁸ Distance should

⁸ Engineering advances may eventually extend the effective service reach of xDSL technologies, better enabling them to service rural and remote areas. For example, Symmetricom is currently testing an ADSL loop extender, a set of active electronics placed in the local loop that may deliver service up to 30,000 feet. <www.symmetricom.com/products/GoLong.html>.

be calculated as the total wire length, not as a line-of-sight measurement. Hence, distance from the CO may be considerably greater once the actual path of the copper loop is considered. The gauge of the copper wire in the loop also tends to reinforce signal loss as distance increases. Data delivered by xDSL over thinner 26-gauge wire will likely not reach as far as that traveling over 24-gauge.

Line quality also impacts the performance of xDSL transmissions. Bridge taps and other line condition problems contribute to signal attenuation. Load coils, used to improve voice band transmissions over long local loops, distort higher frequencies and must be removed from the line for xDSL technologies to function properly.

DLC systems that aggregate and multiplex remote subscriber lines onto fewer transport lines also pose deployment issues for some xDSL variants and usually require some upgrade to existing infrastructure (IEC “Digital”). While even old DLCs are digital, their function was to aggregate a specific maximum volume of voice traffic and they simply were not designed to carry combined bandwidth above 1.54 Mbps. Therefore this constraint means that an older DLC would not readily support even one xDSL line. However, next generation (NGDLC) systems often do support xDSL and higher bandwidths but may not yet be enabled with the necessary line cards.

DLC limitations can be met with a number of solutions including the installation of remote DSLAMs, remote-access multiplexers (RAMs), and xDSL line cards (IEC “Extending”). Remote DSLAMs function exactly as those located in the CO and, by intercepting and splitting POTS from data channels, function independently of the DLC. Remote DSLAMs can expand and support a significant number of users; however, they require the placement of new equipment vaults, extensive rewiring, and require a relatively significant investment. RAMs function in much the same manner but are less costly, and small enough to fit inside the existing DLC cabinet, limiting the need for rewiring. An individual RAM accommodates fewer lines than a remote DSLAM but is easily expandable by adding more units so long as there is sufficient space in the cabinet. A third solution involves xDSL line cards that fit into the open slots of an NGDLC system. However, expandability is limited to the number of available slots which may also impact the subsequent expansion of POTS service from the DLC. In addition, line cards may involve significant administrative costs related to the matching of proprietary hardware that is not required by the other two solutions. Older DLC systems may also involve extensive rewiring if they are able to accommodate xDSL line cards at all.

Line cards are simply plug-in electronic printed circuit boards that provide a variety of features and functionality for access lines in a telecommunications network (Newton).

xDSL Variants

The differences among xDSL variants relate primarily to how the high frequency signal is modulated, which correspond to differences in throughput rates, transmission symmetry, service reach, and its ability to simultaneously carry POTS service. Other characteristics, such as engineering for setup ease may also impact the performance standards of

each variant. It is important to remember that in many cases, exact engineering standards have not yet been finalized and often change with technology development. The following seven descriptions of xDSL variants largely summarizes material from Aber, ADSL Forum, IEC (“Fundamentals”), and Newton.

ADSL

Asymmetric digital subscriber line is probably the best known of the xDSL variants and has been heavily promoted as the broadband connectivity solution for home and small business use. One reason is that ADSL combines data transmission with POTS capability over a single twisted pair. Similar to voice band modems, data transmission is asymmetric with the downstream rate having greater bandwidth.⁹ Under good line conditions and using 24-gauge wire, ADSL can support the following top downstream bit rates at various distances:

Table 2: ADSL Bit Rates and Distance

Bit rate	Distance	Digital Signal Level
1.54 Mbps	up to 18,000 feet	T1
2.04 Mbps	16,000 feet	E1
6.31 Mbps	12,000 feet	DS2
8.44 Mbps	9,000 feet	E2

Source: ADSL Forum.

ADSL technical standards for putting data into a modulated carrier signal have not yet been settled, an issue which may be slowing investment and deployment of the technology. Of two competing and incompatible technologies, carrierless amplitude/phase modulation (CAP) has the largest penetration in the United States. Discrete Multitone Technology (DMT), however, is the current European standard and has been endorsed by the American National Standards Institute (Newton).

Upstream rates can vary between 16 to 640 kbps. This performance enables ADSL to serve as an economical alternative to leased T1 lines, supporting high-speed Internet access, video streaming and interactive multimedia applications, and remote LAN access. Typically, however, network access providers offer a variety of transmission configurations under 1.54 Mbps since most browser applications do not support higher rates and because of the high cost of bandwidth. In addition, ADSL will not run through unimproved DLC systems.

G.lite

Also known as ADSL Lite, it is an industry effort to develop a less expensive standard for ADSL modems that would be applicable everywhere (an International Telecommunications Union standard). Doing so would allow PC manufactures to bundle and integrate G.lite modems with their products, much as voice band modems are today. Reductions in cost and end-user setup effort are obtained by removing the POTS splitter at the customer end (POTS service is maintained, however). G.lite is also asymmetric, but only provides a maximum downstream rate of 1.54Mbps and an upstream rate of 256kbps at 18,000

⁹ Asymmetry of the transmission is desirable so as to limit the amount of signal coupling, or interference, that is generated when large numbers of twisted pairs are bound in cables. Asymmetry thus allows higher data rates over greater distance (ADSL Forum).

feet. The eventual G.lite-like product, however, may vary as other splitter-less technologies with higher maximum bandwidth are being developed.

RADSL

Rate-adaptive digital subscriber line employs a special ADSL modem technology that senses and adjusts the data transmission rate depending on the changing quality of the subscriber line, much as many voice band modems do. RADSL is otherwise similar to ADSL in terms of POTS capability, data transmission speeds and service reach.

ISDL

ISDN-based digital subscriber line is so named since it uses the same line coding technique as ISDN. The initial product provided symmetric data transmission at 128Kbps out to 18,000 feet, but is a data-only service. One significant advantage of ISDL is that, because of its similarity to ISDN, it can pass through DLC systems and can be terminated in any standard ISDN terminal adapter. Like other xDSL variants, however, it bypasses the circuit-switched network. But unlike other xDSL services, the service reach of ISDL can be extended out to 48,000 feet using ISDN-like repeaters.¹⁰ Where available, ISDL is frequently more expensive than ADSL because of equipment requirements and the need for an additional POTS line, but it may be the only high-speed alternative for more remotely located customers.

VDSL

A very high bit rate digital subscriber line is the fastest of the xDSL technologies operating over a single twisted pair although its service reach is shorter and is a data only service. VDSL can be configured to provide either symmetric or asymmetric transmissions. Maximum up- and downstream standardized rates over various distances are proposed as follows:

Table 3: VDSL Bit Rates and Distance

Distance	Bit rate (Mbps): Asymmetric		Bit rate(Mbps): Symmetric
	downstream	upstream	
1000 feet	51.84	6.48	25.92
3000 feet	25.92	3.24	12.96
4500 feet	12.96	3.24	-

Source: IEC “Very.” Based on ANSI T1E1.4.

VDSL implementation is somewhat easier than ADSL because of the shorter line length, and, because of its high bandwidth, is well suited for video applications such as telemedicine and conferencing. In coming years, some view VDSL as being the telecos technology of choice for providing full-service access comprising voice, data, and video (such as

¹⁰ Other methods of extending ISDL service even further from the CO, up to 100,000 feet, are being developed and tested (Greene).

high-definition television) that would compete against services provided by cable television operators (IEC “Very”).

HDSL

High bit rate digital subscriber line modems use advance modulation techniques to provide symmetric data service using two copper pairs to provide bit-rates up to 1.54Mbps (T1) or, by using three copper pairs, bit-rates up to 2.04Mbps (E1). These transmission speeds are supportable up to 12,000 feet on 24-gauge wire and thus are frequently used by telcos as an alternative to repeated T1 and E2 lines in such places as the subscriber line feeder plant, DLC systems, etc. HDSL is a relatively mature technology and may eventually be supplanted by more advanced versions, such as SDSL.

SDSL

Single line digital subscriber line provides transmission rates identical to HDSL over a single twisted pair but only up to 10,000 feet. Since SDSL can generally be run above POTS frequencies, it is a potential candidate for last-mile connectivity where symmetric data transmission is desired.

Kentucky xDSL Footprint

The deployment of xDSL across the nation has continued to grow, primarily first in larger markets, although at a rate slower than initially projected. Accurate estimates of in-service lines are somewhat difficult to arrive at since service providers furnish the information on a voluntary basis. Third quarter 2000 estimates made by TeleChoice, Inc. put national coverage at approximately 1.7 million lines, of which 67 percent were residential and 33 percent business. Future xDSL subscription growth is anticipated to be robust, exceeding 15 million lines by 2005.¹¹

Subscriber access lines do not normally radiate out in a circular fashion from the CO, but are rather more irregular and ‘box-shaped’ since the twisted pair tends to follow the established street grid.

Two views of xDSL coverage in Kentucky, *potential* and *actual*, are given together in Figures 3 and 4. First, information from the LERG on the location of Class 5 or 4/5 end office switches in the state is used to construct a representation of potential xDSL coverage. It represents a kind of best case scenario by assuming that each CO with an end office switch also houses xDSL modems and line multiplexers. ADSL is used as the standard for depicting the serving area since it is the most widely used and least expensive for residential and small business connectivity. Hence, coverage is represented as 18,000 foot radiating circles projecting from the CO and delineates the outermost boundary from which true ADSL coverage might likely exist. Sub-optimal line quality and the twists and turns of subscriber lines down streets and through neighborhoods would shorten this distance.¹²

¹¹ Copyright 2001, TeleChoice, Inc.

<http://www.xdsl.com/content/resources/deployment_info.asp>

¹² Data giving the specific location of DLCs is not generally available so their potential coverage areas if xDSL enabled is not depicted.

Second, information on the location of actual xDSL equipped COs was obtained and is superimposed over the potential coverage map.¹³

Caution should be used in interpreting the actual coverage data.

Foremost is that the data may be incomplete since the queried data bases includes primarily large providers, such as Bell South, GTE, and Covad. Whereas in Kentucky, there are 20 ILECs, many quite small, who may or may not provide xDSL service. The information does not indicate which xDSL variant(s) is (are) supported, although it is depicted here as being ADSL. Also, as per previous sections, being within the xDSL coverage area of a particular CO does not ensure that service is available to all subscriber lines. Issues such as line quality, actual loop length, and the presence of DLCs will impact individual availability.

However, despite these limitations, the actual coverage information does provide a preliminary and interesting view of the distribution of actual xDSL deployment across Kentucky at a point in time. The potential coverage map, on the other hand, provides a view of what may be possible given a particular set of technology requirements.

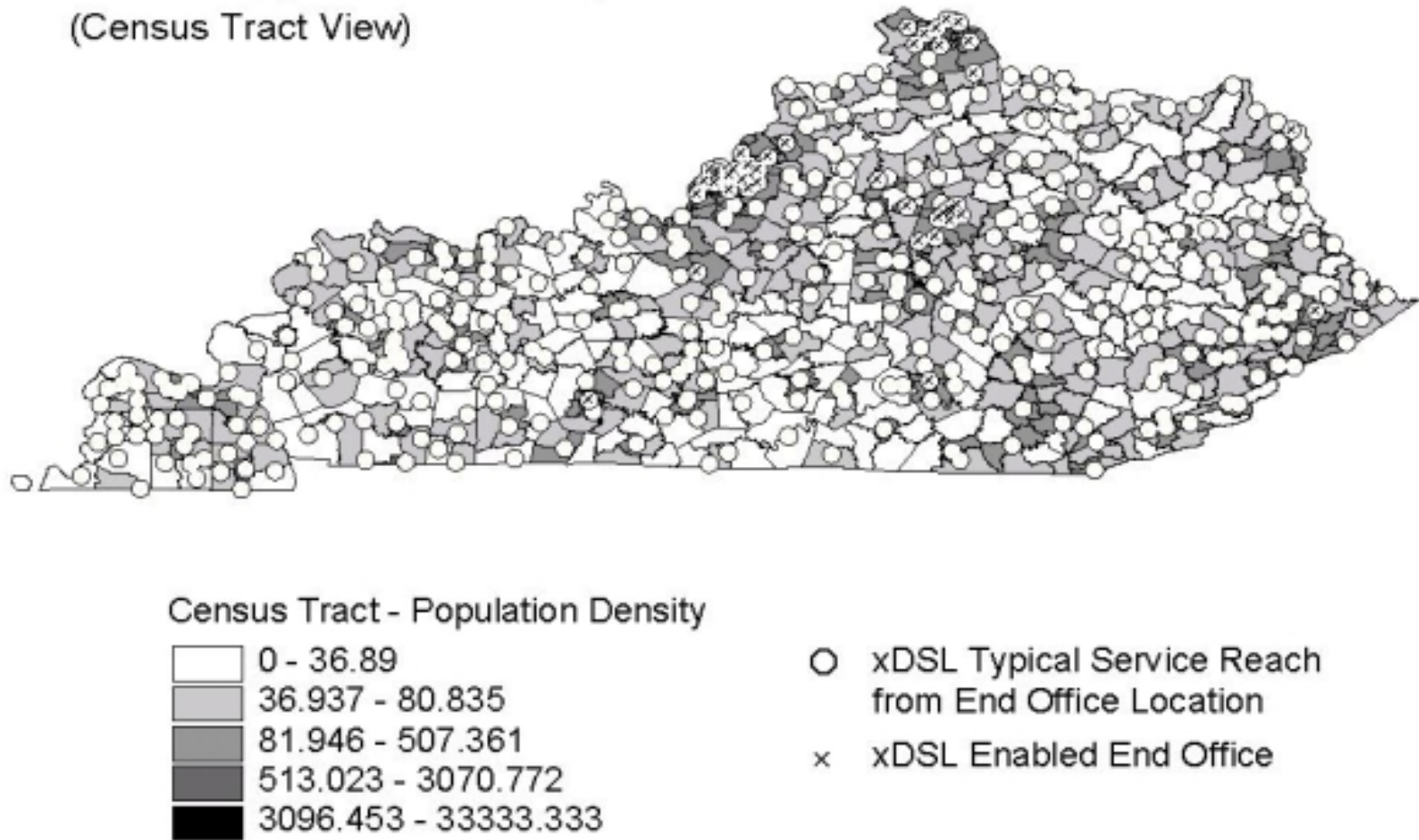
Figure 3 superimposes the potential xDSL coverage map on the depiction of the Kentucky rural-urban continuum by county. What is actually being shown, of course, is the geographic distribution of end offices (and the assumption they are all ADSL enabled). There are 445 end offices in the state, with 126 (28.3 percent) in metro counties and 319 (71.7 percent) in nonmetro counties. End office dispersion is fairly uniform, with at least one office per county, which would be consistent with the notion of universal telephone coverage. There is noticeable concentration, however, of end offices in some of the more urban counties. This is not surprising considering the higher density of population that must be served. Figure 4 presents a slightly different view, with end office locations superimposed over 1990 census tract information which provides for a slightly smaller unit of observation. Again, the most populated areas are served by one to many end offices, while many less populated tracts share end office services. Of course, without specific knowledge of xDSL implementation, this represents only what may be possible, based on one type of implementation configuration.

Figures 3 and 4 also show actual xDSL deployment across the state. The data indicated 54 separate sources of service provision (i.e., sets of xDSL equipment). However, co-location of equipment in the same CO

¹³ Unlike specific switching functions, mapping the geographic distribution of enabled xDSL technologies is less straightforward. One reason is that xDSL is not a switching function and is consequently not reported in the LERG. However, various organizations do maintain searchable databases of xDSL availability as a service to individual consumers and other telecommunications providers. Information used in this report consisted of Common Language Location Indicator (CLLI) codes and ownership for Kentucky switches or wire centers that a database query indicated as having xDSL service available on or about 19 January 2001. This information was subsequently merged with LERG data to determine location (data obtained from TelcoExchange).

Figure 4

Kentucky xDSL Footprint (Census Tract View)



Source: Data from LERG, July 1, 2000 and TelcoExchange, Jan. 19, 2001.

accounts for 22 percent of these, leaving 42 unique service provision locations. Most xDSL service is installed at COs clustered in and around three metro county areas representing 91 percent of the equipment deployed. A mere 5 xDSL enabled COs serve nonmetro counties. The census tract view shows that even within the nonmetro counties, deployment occurs in those areas with a higher population concentration.

xDSL deployment appears to follow a pattern similar to the distribution of ISDN service (Figure 2), with distinct areas of availability corresponding to higher consumer density and hence demand found in metro counties and densely populated census tracts.¹⁴ What Figures 3 and 4 also show is that significant additional investment in xDSL equipment would need to be made, mostly in rural areas, just to achieve the level of potential coverage depicted here. In addition, there is a considerable amount of 'white space', between potential coverage zones that perhaps represent areas serviced by DLC systems or lengthy local loops. Extension of ADSL service to DLC systems and remote areas will require additional investment if universal xDSL service is the goal.

ADSL Pricing in Kentucky

Although several variants of xDSL are available in Kentucky, by far the most common and least expensive is ADSL. Despite this, ADSL is primarily available only in or near more urban areas such as Louisville, Lexington, and Cincinnati. While it is somewhat problematic to systematically determine exactly which COs provision ADSL, the cost of service is more widely advertised. Indeed, many ISPs and LECs are beginning to aggressively promote the technology, especially in larger, denser markets, in an effort to head off competition from cable Internet service providers, who for a time appeared to be gaining hegemony in the residential broadband market (Rowley).

Activation of any type of xDSL line requires the participation of two parties: the incumbent or competitive LEC (for use of the local loop, CO facilities, and equipment) and a local or national ISP (who provides the final Internet connection and some other web-based services to customers at that location). Thus, there are charges to the LEC for the access line service, the ISP for Internet service, the purchase price or rental for the xDSL modem, and sometimes an initial setup fee. In this respect, the distribution of charges is not unlike dial-up modem service. In addition, customers must also install a network card in their computers to interface with the xDSL modem and may need to make relatively minor modifications to their inside wiring.

An unscientific, web-based survey of ADSL providers in Kentucky finds a wide array of service levels for residential and business use. Differences among service levels and differences in pricing for

¹⁴ See Malecki ("Telecommunications") for an analysis of the relation of population and business activity density to the frequency of advanced telecommunications services.

apparently similar levels of service are related to not only the raw transmission speed of the connection from residence to DSLAM, but also to the amount of bandwidth the customer is entitled to in the connection from the DSLAM to the ISP and to the Internet, and the offered quality of service. In many cases, particularly for residential use, the quality of service offered by the ISP is on a best effort basis, with no particular guaranteed bandwidth or error rate.

Table 4 presents several representative levels of service and charges for residential ADSL. However, many different service level configurations are available depending on the particular ISP and the location. The range in ISP charges, in general, reflects differences in service level CIRs; however, the differences are not always explicitly stated. Line charges, in contrast, tend to be fairly fixed at each configuration but increasing as the expected transmission rate increases. Yet these two types of charges are not always delineated, and only a monthly service charge is reported. In most cases, customers must either rent or purchase an xDSL modem, averaging \$200. Various other one-time installation fees may also apply depending on the type of service although these are sometimes waived during promotional efforts.

Table 4: ADSL Residential Service

Speed (Kbps) (down/up)	Line Charge	ISP Charge	Total Monthly	Setup Fee
768/128	33-45	7-68	33-101	0-50
384/384	45-53	25-45	80-101	0-50
768/768	~68	60-75	119-143	0-50
1500/768	95-215	100-190	195-405	0-100

Business-level ADSL service is normally more costly than residential service at comparable transmission rates. The cost difference is generally not related to the access line, this being fixed, but rather depends on the types of additional services offered by the ISP and anticipated costs due to differences in expected data traffic between business and residential users. Often the ISP makes no distinction between residential and business service, while others offer a number of distinct service packages. Additional monthly ISP charges for business service was found to run between 0 and 45 percent higher than residential service. There may also be additional expenses for routers and other equipment, such as for the interface between the access line and a LAN.

Conclusion

In just a few years, the Internet has become an increasingly more important means of communication among individuals, and the medium of choice for business processes including advertising, procurement and sales, and internal and external communication. All levels of government are also adopting the Internet as an important means to disseminate information and manage their contact with vendors and citizens. This rapid growth has had two important effects – the first is that it is now accepted that being connected to the Internet at your home or office is almost a prerequisite for being a full participant in the modern economy.

The second, while currently less obvious, is that simply being connected is no longer enough. On an almost monthly basis, the content on websites is modified to offer more information and a more sophisticated design. In turn this requires people who connect to the site to have both a powerful computer and most importantly a faster Internet connection if they are to effectively communicate.

While it is always possible to purchase a more powerful computer, increasing the speed of an Internet connection is generally not as easy. Higher speed access simply may not be available if the underlying telecommunications infrastructure does not support it. While great advances have been made in telecommunications using telephone wires, coaxial cable and wireless means, each of these approaches has both technological and price constraints on its availability. Of the three technologies, the one based upon the PSTN is the most commonly available in terms of geographic area covered, and is typically the least expensive to use for households and small businesses.

This report examines how the nature and distribution of the PSTN wire line infrastructure and CO switching impacts the last mile connectivity challenge in Kentucky. While ubiquitous, simply looking at POTS availability is not sufficient, as it only allows VBM (narrow band) transmission, and even then maximum speeds are often not available. Alternatives exist to VBM, but there are fewer options in rural areas, and they frequently cost more for the same level of service. Newer modem technologies that take advantage of the existing PSTN infrastructure, such as xDSL, promise to provide relatively low cost, high-speed, last mile connectivity.

Rural areas, however, will still have a harder time because access line distance in rural areas is frequently beyond the capability of existing, commonly available technologies. Additional investment and infrastructure upgrade in rural areas normally lags behind that of more densely populated areas because unit costs are higher (lower density) while unit revenues are lower (less use) for telco equipment (Parker). Thus many parts of the state are unlikely to receive high-speed Internet access through their telephone lines either because it is technologically impossible to provide or because the cost to the telephone company of implementing the technology in that area exceeds the potential revenue

base. While technological improvements may address the first problem, they are less likely to resolve the second one.

The current distribution of ISDN availability and the emerging pattern of xDSL deployment across Kentucky confirm that rural areas lag behind in advanced broadband last mile access. This suggests that, over time, if technology continues to evolve as it has in the last decade, the digital divide between rural and urban areas will increase. However, smaller urban centers where a central office switch is located may be able to receive improved service as technology allows broadband access through remote methods.

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