II. Broadband Model Results

Wideband Deployment Assumptions and Costs

This paper provides data on the costs to provide classrooms with access to the PSN via broadband technology. These broadband results supplement previous wideband research results published by the Department of Education, and by Rothstein and McKnight, hereinafter referred to as the Wideband Papers. The term "wideband" refers to the focus of those papers on access technology capable of providing data rates and services up to 1.544 Mbps. This paper expands the range of services that might be considered for public schools by provision of fiber-optic broadband access, and gives new total system costs for both LEC network infrastructure and school premises equipment. To get a sense of the difference between the wideband and broadband transmission rates, the contents of Tolstoy's War and Peace can be sent in twenty-six seconds with wideband (1.544 Mbps) and in one second with broadband (greater than 45 Mbps). See Section III for a description of the definitions and assumptions for this wideband deployment.

The Wideband Papers estimate total system costs using these items for five different service configurations involving local schools, a district office, and levels of service to the local schools. The configurations progress from a model consisting of the most basic service level, with a line and modem connecting a school to its district office, up to a model consisting of full, ubiquitous wideband connection for the local school to the telecommunications network (hereinafter referred to as the "wideband model").

The estimated costs for nationwide deployment of this wideband model are $51 billion in startup costs, with $4 billion in annual operating expenses.

Broadband Model Results

Two deployment schedules for public schools are compared - a 20-year nationwide broadband deployment and a 5-year broadband accelerated deployment. Three access-to-technology scenarios are modeled for each of the two schedules. These scenarios (Figure 1) are teacher only (only one computer per classroom), team of students (seven computers per

5For further information regarding broadband technology see Carol Weinhaus, Linda Garbanati, et al., Overview of New Technology Deployment Model: Broadband with Associated Depreciation and Overheads, Telecommunications Industries Analysis Project, Public Utility Research Center, College of Business Administration, University of Florida, March 15, 1995. See also the 1995 User Guide associated with the model.

6See Rothstein and McKnight, Connecting K-12 Schools and Technology and Cost Models of K-12 Schools.

7Greater than 1.544 Mbps.

8Assumes a 2400 baud modem.

9Costs for the other configurations range from $.07 billion in startup costs with $.15 billion in annual operating expenses for the most basic configuration up to the high estimate of the wideband model of $113.5 billion in startup costs and $10 billion in annual operating expense. For more information, see the Wideband Papers.
Figure 1: Three Scenarios for Broadband Deployment to Public Schools: Kindergarten through Twelfth Grade

Scenario 1

Teacher-Only Access:
1 PC

Scenario 2

Team-of-Students Access:
7 PCs

Scenario 3

Universal Access:
26 PCs

Common Assumptions (per School):
- 2 Video Instructional Areas

Common Assumptions (per Classroom):
- 1 Teacher and a Class of 25 Students
- 1 Telephone
- 1 Scanner
- 1 Printer

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II. Broadband Model Results, cont.

classroom),\textsuperscript{10} and universal (every student and teacher has a computer). For descriptions of these schedules and scenarios, see Section III.

For a description of the schedules and the three scenarios see Section III. The results indicate the following points:

- The range of total costs for the 20-year broadband deployment is $14.7 billion for the teacher-only access scenario to $118.3 billion for the universal access scenario. The range for the 5-year accelerated deployment\textsuperscript{11} for these two scenarios is $28.6 billion to $204.4 billion (Figure 2).

- If broadband deployment to public schools is accelerated to five years instead of integrated as part of a 20-year nationwide deployment, LEC network investment costs are approximately five times as much (Figure 3). Acceleration of deployment to the schools produces significantly higher costs. This is due to the fact that more equipment is purchased in the early stages when prices are higher and to the fact that there will be little sharing of common facilities and civil works with other customers.

The pattern in Figure 2 LEC investment indicates the 5-year accelerated schedule provides less opportunity for sharing installation costs among all customers and requires buying sophisticated equipment at a premium price – early in the equipment’s market life when prices for net technology tend to be higher. The 20-year schedule shows the cost advantages associated with a staged rollout of all equipment. In the 20-year schedule, costs for network investment are shared over all available services and investment is stimulated by wider market demand and an integrated cost-effective modernization of facilities.

- LEC network investment costs are dwarfed by the school costs, especially as the number of computers per classroom approaches the number of students per classroom. In the case of universal deployment of computers (a computer on every desktop), even the expense associated with software upgrades and Internet access charges rapidly exceeds the LEC network investment costs. LEC network investment costs are $2.2 billion for the 20-year deployment (Figure 4) and $10.2 billion for the 5-year accelerated deployment (Figure 5). Depending on the scenario, these costs range from 1.9% to 35.6% of total costs.\textsuperscript{12}

This pattern of relatively high investment by schools and low investment by LECs is especially evident in the most extensive scenario (universal access, Figures 4 and 5).

\textsuperscript{10}Assumes in each classroom the teacher has a PC and twenty-five percent of the students have a PC.

\textsuperscript{11}Extended to include costs over twenty years.

\textsuperscript{12}For data for individual years, see Section VII, Appendix C, Figures 24 through 29.
Figure 2: LEC Investment and School Costs by Category: Broadband Deployment to Public Schools, 5-Year Accelerated and 20-Year

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>Dollars (in Billions)</td>
<td>Percent</td>
<td>Dollars (in Billions)</td>
</tr>
<tr>
<td>School Annual Software Expense and Internet Access</td>
<td>$2.7</td>
<td>9.3%</td>
<td>$18.7</td>
</tr>
<tr>
<td>School Investment (including replacements)</td>
<td>$15.7</td>
<td>55.1%</td>
<td>$40.7</td>
</tr>
<tr>
<td>Network Investment</td>
<td>$10.2</td>
<td>35.6%</td>
<td>$10.2</td>
</tr>
<tr>
<td>Total</td>
<td>$28.6</td>
<td>100.0%</td>
<td>$69.6</td>
</tr>
</tbody>
</table>

5-Year Accelerated Broadband Deployment:

| School Annual Software Expense and Internet Access | $1.4 | 9.2% | $9.5 | 24.7% | $35.2 | 29.8% |
| School Investment (including replacements)        | $11.1 | 75.9% | $26.7 | 69.6% | $80.9 | 68.4% |
| Network Investment                                | $2.2 | 14.9% | $2.2 | 5.7% | $2.2 | 1.9% |
| Total                                            | $14.7 | 100.0% | $38.3 | 100.0% | $118.3 | 100.0% |

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Figure 3: Comparison of Total LEC Investment Costs: Broadband Deployment to Public Schools, 5-Year Accelerated and 20-Year Deployment

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* In the 5-year accelerated deployment, replacement costs for school investment in computers, etc., is minimal in relationship to the initial investment and, therefore, is not immediately visible in years 6 through 20. Modeling the costs out to 20 years allows comparisons with the 20-year deployment.
Figure 5: Comparison of School Costs with LEC Network Costs:
20-Year Broadband Deployment, Universal Access (Scenario 3)

* In the 5-year accelerated deployment, replacement costs for school investment in computers, etc., is minimal in relationship to the initial investment and, therefore, is not immediately visible in years 6 through 20. Modeling the costs out to 20 years allows comparisons with the 20-year deployment.

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II. Broadband Model Results, cont.

While not as extreme, this same pattern also holds true for the simplest scenario (teacher-only access) which provides only one PC per classroom.\textsuperscript{13}

- LEC network investment costs are indifferent to the number of PCS per classroom (Figures 4 and 5). Data rates supported by broadband equipment and fiber-optic cable are so great that these costs are insensitive to the variation in the demand for data services due to the number of PCS.

- The incremental investment per student per year (Figures 6 and 7) indicates that the universal access scenario costs approximately twice as much as the team-of-students access scenario and approximately seven times as much as the teacher-only access scenario. Incremental investments remain relatively constant over time for these two less extensive deployments.\textsuperscript{14}

- In terms of the incremental investment per student per year, the decision to accelerate broadband deployment beyond the nationwide deployment produces an effect that isn't erased with time. This difference is most evident in the comparison of 5-year and 20-year deployments of the universal access scenario (Figure 8). By the sixth year, the investments diverge dramatically. To a lesser degree, this same pattern appears in the teacher-only access and in the team-of-students access scenarios.\textsuperscript{15}

- In 1992 public school expenditures per student were approximately $5,200. A comparison of this number with the results from the model in Figures 6 and 7, indicate potential for increased expenditures. However, as noted before, it is difficult to determine the impact of new technology on existing expenditures. For the universal access scenario, incremental investments per student may double current expenditures, while for the teacher-only access scenario, investments may increase by ten percent.\textsuperscript{16}

\textsuperscript{13}See Section V, Appendix A, for similar comparisons for Teacher-Only Access (Scenario 1, Figures 13 and 14), and for Team-of-Students Access (Scenario 2, Figures 15 and 16). Appendix A also contains additional charts with the y-axis scaled to indicate the patterns occurring among each scenario's categories (Figures 17 through 21). The scenario for Figure 4 is not included in this set because in this case the y-axis is already scaled to the data set.

\textsuperscript{14}For background numbers, see Section VII, Appendix C, Figure 30.

\textsuperscript{15}See Section VI, Appendix B, for similar comparisons for Teacher-Only Access (Scenario 1, Figure 22), and for Team-of-Students Access (Scenario 2, Figure 23). For background numbers, see Figure 30.

Figure 6: Incremental Investment per Student per Year for Three Access Scenarios:
5-Year Accelerated Broadband Deployment

*Modeling the costs out to 20 years allows comparison between the 5-year accelerated and the 20-year deployment schedules.

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Figure 7: Incremental Investment per Student per Year for Three Access Scenarios: 20-Year Broadband Deployment

Universal Access

Team-of-Students Access

Teacher-Only Access

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Figure 8: Incremental Investment per Student per Year for Universal Access (Scenario 3):
5-Year Accelerated and 20-Year Broadband Deployment

*Modeling the costs out to 20 years allows comparison between the 5-year accelerated and the 20-year deployment schedules.

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III. Wideband and Broadband Deployment Definitions and Assumptions

Wideband Deployment Assumptions and Costs

Figures 9 and 10 illustrate the wideband network used in the Wideband Papers. In the Wideband Papers, the authors included estimates for the following cost components:

- Average tariffed rates for selected services,
- Customer (school) provided equipment,
- Re-wiring the school and installing equipment,
- Retrofitting the schools,17
- Teacher and staff training, and
- Technical support.

The most extensive deployment model in the Wideband Papers defines total system costs for a full, ubiquitous wideband connection for local schools and district offices to the telecommunications network and includes the following:

- A personal computer (PC) on every desk,
- A Local Area Network (LAN) with file servers and routers in each school, and
- Wideband interconnections to other schools in the district and to the network.

Broadband Deployment Definitions and Assumptions

This paper provides the costs for connecting the schools to the network using two deployment schedules – five years and twenty years – for broadband access and school equipment. Both schedules assume a nationwide, ubiquitous deployment of a broadband infrastructure in the LEC telecommunications networks over a twenty year period. To provide valid comparisons between the two deployment schedules, the modeling cost results are based on comparisons of twenty year periods for three access-to-technology scenarios (teacher-only, team-of-students, and universal). However, the differences between the two schedules are as follows:

- **20-Year Schedule**: Assumes all schools will have broadband access and equipment by the end of the twenty years. It assumes that the deployment pattern in the schools matches the nationwide deployment pattern so that the schools receive access to the new technologies at the same rate as the rest of the nation.

- **5-Year Accelerated Schedule**: Assumes the schools will have broadband access and equipment within five years and that the deployment will be uniform

17Customer (school) provided equipment includes routers, servers, and PCS. The retrofitting costs include asbestos removal required to install new telephone and electrical wires, new environmental systems to protect the hardware, and upgrading the electrical systems to support both new hardware and environmental systems.
Figure 9: Wideband Deployment Architecture

Figure 10: Simplified Block Diagram for Wideband Deployment*

*Adapted from R. Rothstein and L. McKnight, "Technology and Cost Models of K-12 Schools on the National Information Infrastructure," Figure 7, p. 19.
III. Wideband and Broadband Deployment Definitions and Assumptions, cont.

throughout the five-year period. In this case, the schools receive new access technologies long ahead of the entire nation. This deployment requires a special design and does not match the national deployment. The 5-year schedule is an accelerated network deployment.

In order to make comparisons between the two schedules, additional school investment and expenditures (i.e., periodic equipment replacement and software upgrades) for years 6 through 20 are included in the 5-year schedule results. Both deployment schedules also assume the following:

- Broadband is defined as technology that supports multiplexed data rates in excess of 45 Mbps.

- Only costs for kindergarten through 12th grade public schools will be considered.

- School numbers include equipment and software costs for upgrades every five years.

- All data concerning school size, classroom size, number of students, number of school districts, etc., are from public sources.¹⁸ The basic statistics are as follows:

  \[
  \begin{align*}
  &15,025 \quad \text{public school districts}, \\
  &84,501 \quad \text{schools}, \\
  &42,586,000 \quad \text{public elementary and secondary school students, and} \\
  &25 \quad \text{students per classroom.}
  \end{align*}
  \]

- The broadband service platform (illustrated in Figures 11 and 12) provides enough bandwidth for data transfer, faxing, voice communications, and two way video services.¹⁹


¹⁹The broadband deployment used in this paper is based on the residential deployment for broadband developed in the New Technology Deployment Model and described in the Overview of the New Technology Deployment Model and the 1995 User Guide.
Figure 11: Broadband Deployment Architecture

For definitions of broadband technology architecture and assumptions, see Carol Weinhaus, Linda Garbanati, et al., Overview of New Technology Deployment Model: Broadband with Associated Depreciation and Overheads, Telecommunications Industries Analysis Project, Public Utility Research Center, College of Business Administration, University of Florida, March 15, 1995. See also the 1995 User Guide associated with the model.

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Figure 12: Simplified Block Diagram for Broadband Deployment

For definitions of broadband technology, architecture and assumptions, see Carol Weinhaus, Linda Garbanati, et al., Overview of New Technology Deployment Model: Broadband with Associated Depreciation and Overheads, Telecommunications Industries Analysis Project, Public Utility Research Center, College of Business Administration, University of Florida, March 15, 1995. See also the 1995 User Guide associated with the model.

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Variations in costs are driven by the amount of equipment (PCS, telephones, etc.) assumed to be present in each classroom. Figure 1 illustrates the three scenarios modeled in this paper:

<table>
<thead>
<tr>
<th>Number of Personal Computers (PCS) per Classroom</th>
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<tbody>
<tr>
<td>Scenario 1: Teacher-Only access</td>
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<tr>
<td>Scenario 2: Team-of-Students Access</td>
</tr>
<tr>
<td>Scenario 3: Universal Access</td>
</tr>
</tbody>
</table>

Common to all scenarios are the following service assumptions: 2 video instructional areas per school and 1 telephone, 1 scanner and 1 printer per classroom.

- Incremental investment per student per year is calculated by dividing the sum of costs calculated for that year and for all prior years by the total number of students that have been provided broadband network access and desktop equipment.

- Incremental investments per student are only modeled for the deployment of broadband technology. The impact on existing education costs is not included in this paper. Since it is hard to determine how technology might be used, it is difficult (if not impossible) to determine how investment in technology might replace other costs and to what extent.

- All costs are expressed in current dollars:

- The cost includes an annual expense for Internet access and usage based on current rates and projections.20

**Definition of Costs for Broadband Deployment**

The costs are defined as costs incurred by LECs to upgrade their networks to provide broadband services to the school and as costs for customer provided equipment that would be required by the schools. The results divide total costs into the following three categories:

---

III. Wideband and Broadband Deployment Definitions and Assumptions, cont.

- **Network Investment:** Includes all LEC investment costs.

- **School Investment:** Includes costs for PCS and other equipment such as telephones, televisons, video equipment, scanners, printers, PBXs, and file servers, as well as training, school retrofitting for appropriate asbestos removal and air-conditioning and electrical upgrades, LAN interconnection and other wiring, and periodic equipment replacements.

- **Annual School Software Expense and Internet Access Costs:** Includes operational and educational software, Internet fees, and upgrading annual software expenses.

This paper focuses on installation costs incurred by schools and by LECs. This paper does not address how these costs should be recovered. Therefore, tariffed rates for telephone services or enhanced broadband services are excluded from the broadband scenarios modeled. Ongoing expenses for maintenance and operations are also excluded from all costs.

21 As part of the deployment of the broadband network, the model assumes that schools will use Private Branch Exchanges (PBXs) – switches that are part of the school’s network – to handle the switching associated with their internal networks and for access to the National Information Infrastructure (NII). However, schools may select the network switching solution that best fit their own needs. The choices may be a PBX or a LEC central office switching service, such as Centrex, or other services.

22 Costs of training existing teachers are included. New teachers are assumed to have been trained during college and costs for this training are therefore excluded. Note that teachers may also train one another.

23 Network Infrastructure costs are accounted for by tariffed rates in the Wideband Papers.
IV. Public Debate over Expenditures for Schools

Public Debate over Expenditures for Schools

While this paper provides data for the debates over the deployment of technology to the schools, technology deployment is only one area in a larger debate over public expenditure for schools. There is general agreement that the trend towards global, competitive markets means that U.S. workers will need new skills to continue to play a leading role in the world economy. However, different people have different views on how schools should use and obtain information technologies to prepare students for the future.

One view is that the federal government should play a leading role in getting broadband services to schools. This view suggests that schools are underutilizing information technologies. Few schools in the U.S. have more than one or two telephone lines, even fewer have a telephone per room, and fewer still have modems and communications lines for computers. For example, the National Education Association and Federal Government have found that most schools are not equipped to make full use of computers and only twelve percent of the classrooms have a phone line. The advancements in new technologies coupled with their absence in public schools has led to government initiatives. Two such responses are the FCC's challenge to the communications industries to connect classrooms and libraries to the PSN and the Clinton Administration's National Information Infrastructure (NII) initiative that emphasizes school access to the PSN.

Another view is that heavy involvement by the federal government is counter-productive. This view suggests that parents, teachers, other local school officials, and students have a better grasp of their specific situations. Information technologies may or may not improve students' learning. For example, sometimes a leak in the roof takes precedence over communications needs. Also, they may want to apply new technologies in ways that would not fit a federal framework. This view concludes that flexibility and local initiatives are key in preparing students for world-class competition.

It is possible to mix these two views. In this case the nationwide deployment and individual tailored deployments by communities and/or states are not mutually exclusive. For example, there might be broad federal policies outlined with implementation given to the states.

24 Increasing the numbers and availability of telephone lines raises management issues for schools as they try to control students making long distance calls.


IV. Public Debate over Expenditures for Schools, cont.

Regardless of whether a person subscribes to one of these views, or yet another view, knowing the cost of technology is important. Educators will be purchasing technology. Therefore, policy makers need to understand the impact of these purchases on school budgets. The following issues are key:

- Who should receive funding? Public schools? Private schools? Home learning programs?
- Who will pay for school expenses? What are the payment structures and mechanisms?
- Who decides where educational funds should be spent?
- What is the role of communications technologies? Who will pay for their deployment? Should any technologies be mandated?

Infrastructure will be necessary to extend the use of computers, both in numbers and in application. This infrastructure would allow the nation's public school classrooms and libraries to access a worldwide information network. However, constructing this infrastructure is only part of the equation. Another critical step is to develop a framework that allows teachers and students to apply electronic communications where it enhances learning.
V. Appendix A: LEC and School Cost Charts

Figure 13: Comparison of School Costs with LEC Network Costs:
5-Year Accelerated Broadband Deployment, Teacher-Only-Access (Scenario 1)

*In the 5-year accelerated deployment, replacement costs for school investment in computers, etc., is minimal in relationship to the initial investment and therefore is not immediately visible in years 6 through 20. Also, modeling the costs out to 20 years allows comparisons with the 20-year deployment.

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Figure 14: Comparison of School Costs with LEC Network Costs:
20-Year Broadband Deployment, Teacher-Only-Access (Scenario 1)
V. Appendix A: LEC and School Cost Charts, cont.

Figure 15: Comparison of School Costs with LEC Network Costs:
5-Year Accelerated Broadband Deployment, Team-of-Students Access (Scenario 2)

*In the 5-year accelerated deployment, replacement costs for school investment in computers, etc., is minimal in relationship to the initial investment and therefore is not immediately visible in years 6 through 20. Also, modeling the costs out to 20 years allows comparisons with the 20-year deployment.

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V. Appendix A: LEC and School Cost Charts, cont.

Figure 16: Comparison of School Costs with LEC Network Costs:
20-Year Broadband Deployment, Team-of-Students Access (Scenario 2)

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