Chapter 1: Networking Technology Adoption

1.1 Background and Motivation

Networking technologies have network externalities – the value a consumer derives from the technology increases with the number of people that own the technology. Telephones are an excellent example. If only one person owned a telephone it would be uninteresting. What makes a telephone desirable is that it allows consumers to use it to communicate with others who have one. The more people that have telephones, the more useful having a telephone becomes.

Networking technologies are also enabling technologies. They allow consumers to interact in ways that were not possible before the existence of the technology. The telephone brought the ability to communicate instantly with people from around the globe. Broadband connectivity and fiber-to-the-home extend that communication to include streaming media, video teleconferencing, telemedicine and many other applications yet to be developed.

Fiber-to-the-home (FTTH) was chosen as a case study for networking technology adoption because it is a technology that is still in the early stages of development and deployment. There is no dominant fiber-to-the-home technology and change is still possible. Fiber-to-the-home also brings with it many policy related issues associated with the Internet and with telecommunications in general. An understanding of how key factors interact and how different adoption rates can be brought about is crucial to deploying this technology in a way that will encourage user adoption.

The Internet as a communications network and commerce enabler has been experiencing exponential growth, both in terms of users and in terms of bandwidth consumed, for many years. The bandwidth used by applications on the Internet has grown from the early text-based days of email, Usenet, and gopher to the advent of the World Wide Web, peer-to-peer applications, and streaming media.

People are no longer limited to simple text-based applications, but can use broadband (i.e., high bandwidth) connections to view lectures or download music and movies over the Internet. The Internet has moved from use by academics at research universities to use by the public at large, to use by businesses and ultimately to use in the home.

Providing broadband telecommunications to the home is not a new idea, though its definition varies widely. Trial fiber-to-the-home deployments in the United States, England, and France began as early as the mid-to-late 1980s (Esty, 1987; Rowbotham, 1989; Shumate, 1989; Veyres & Mauro, 1988).

High-speed service, or today's broadband, is defined by the Federal Communications Commission (FCC) as being at least 200 kbps in either the customer-to-provider or provider-to-customer direction. While this definition distinguishes between 56 kbps dialup services and higher speed services, it neglects to distinguish across a wide range of data speeds. What is considered broadband today will likely not be so labeled in the future, just as the 300 bps modems of the early 1980s pale in comparison to today's 56 kbps modems.

The FCC chose 200 kbps as its delimiter in 1999 because of a belief that this speed was enough to support the most popular applications, such as web browsing at the same speed as one could flip the pages of a book (Federal Communications Commission, 2002). Recognizing that the capability to send and receive information at high speeds was important, the FCC also defined advanced telecommunications service as having speeds of 200 kbps in both directions.

However, the FCC seemingly disregarded the fact that the data speeds needed for streaming music or video or for large data transfers far exceed those of reading a book.

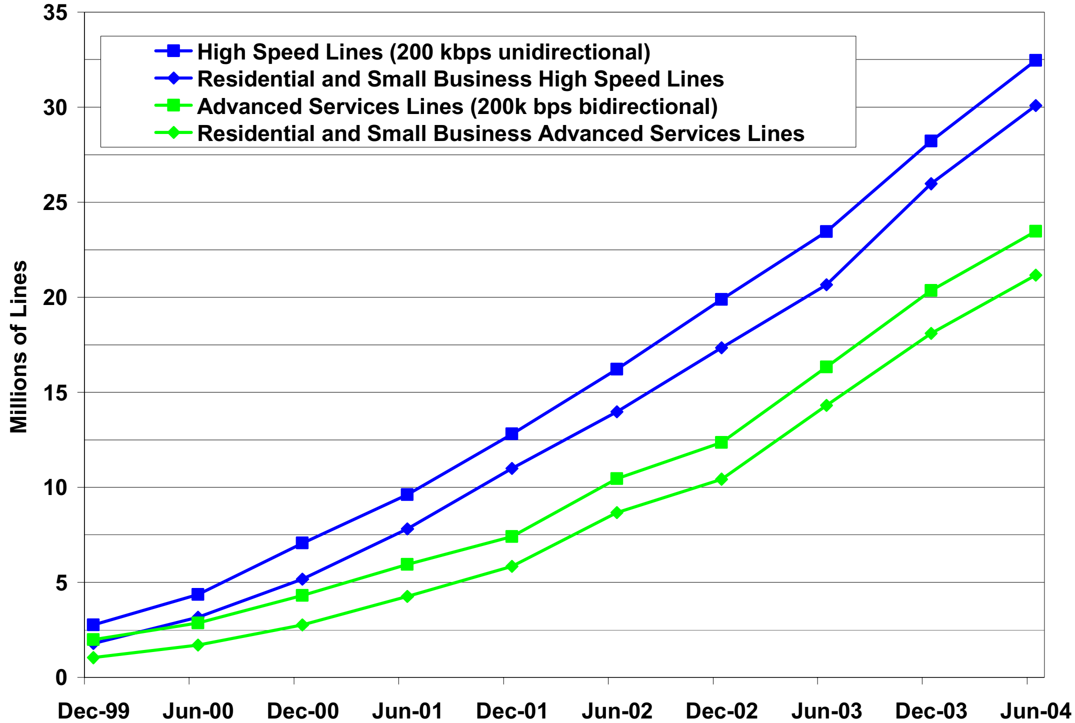

Figure 1.1: Deployment of High Speed and Advanced Services Lines

The notion of advanced services lines, or connections that can deliver high-speed service in both directions, is similar to the definition of broadband developed by the Committee on Broadband Last Mile Technology of the National Research Council. The Committee provides two ~~following~~ definitions of broadband:

1. Local access link performance should not be the limiting factor in a user's capability for running today's applications.
2. Broadband services should provide sufficient performance – and wide enough penetration of services reaching that performance level – to encourage the development of new applications (National Research Council Committee on Broadband Last Mile Technology, 2002).

The FCC's definition of broadband falls squarely under definition one above, assuming the use of the dominant applications from 1999. In order to ensure that the ability to run today's and future applications continues to be met, and under a mandate from the Telecommunications Act of 1996, the FCC has been collecting data on both high speed lines and advanced services lines twice a year since December of 1999. Any facilities-based company that provides 250 or more high-speed service lines in a given state is required to report information on its services and customers twice a year. These providers are also required to report the fraction of lines that are connected to residential and small business customers. The number of high-speed and advanced services lines as reported to the FCC is shown in Figure 1.1. The FCC tracks both total high-speed and advanced services lines and also the number of residential and small business lines.

As shown in the figure, the deployment of both advanced services and high-speed lines is increasing. The deployment of advanced services lines lags that of high-speed lines in both categories of deployments. In the first half of 2004, total high-speed lines grew by 15% to nearly 32.5 million lines; total advanced services lines by 15% to 23.5 million lines; high speed residential and small business lines grew by 16% to 30 million lines; and advanced services residential and small business lines grew by 17% to 21 million lines. The number of lines deployed to customers continues to grow, although this represents lower growth rates than previous periods.

A study by the Department of Commerce's National Telecommunications and Information Administration based on the U.S. Census Bureau current population survey, estimated that approximately 55% of U.S. households had Internet connections in September 2003 (National Telecommunications and Information Administration, 2004). Figure 1.2 shows the breakdown of residential and small business advanced services lines by technology.

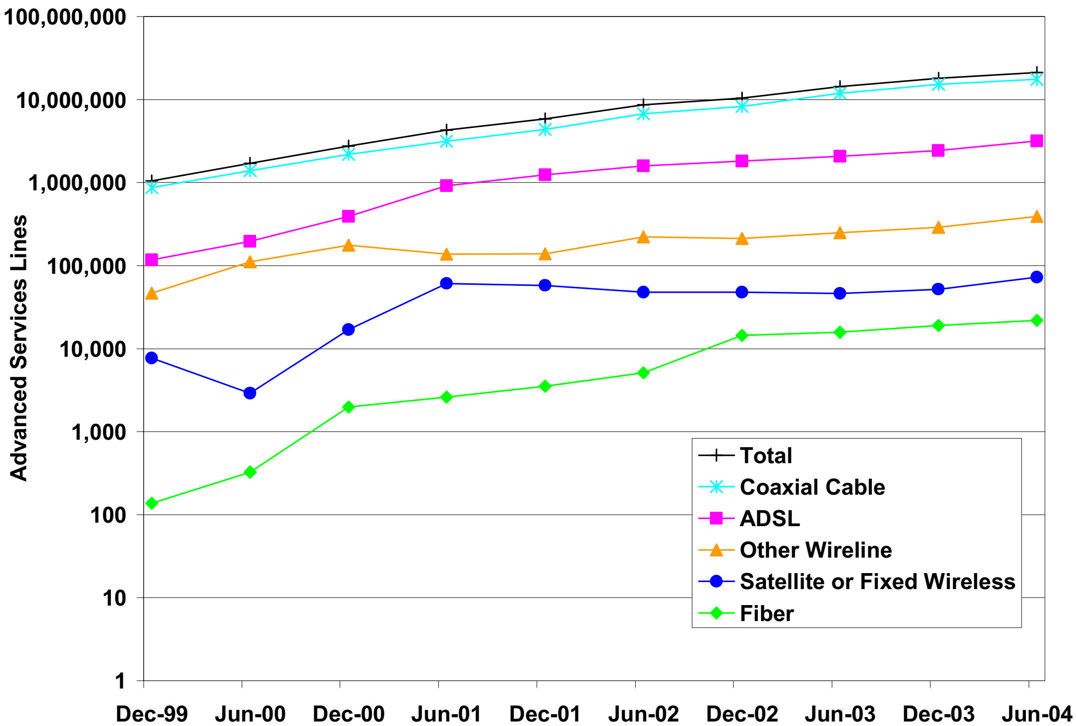

Figure 1.2: Breakdown of Residential and Small Business Advanced Services Lines by Technology (Log Scale)

~~As recognized by the first definition of broadband by the Committee on Broadband Last Mile Technology,~~ an end user's use of the Internet is limited by the speed of the slowest link. For most end users this is in the first mile connection between the user and their service provider (also sometimes called the last mile or the access network). Many users today connect via dial-up connections at 56 kbps, and many businesses are connected at 1.5 Mbps.

Today's residential broadband services operate primarily over copper wire. Specifically, as shown in Figure 1.3, coaxial cable (cable modems) and ADSL (asymmetric digital subscriber line) make up approximately 96% of today's residential and small business advanced services lines. Coaxial cable is dominant in the market, with ADSL as a far second, and all other technologies making up one to two percent of the market. The percent of fiber lines is barely visible in the figure as the slightly darker line between ADSL and "other wireline", since fiber lines make up under 1% of the deployed lines in any given time period. The peak data rate of copper in the first mile is in the tens of Mbps. Today's optical fiber has a limit of 10 Gbps.

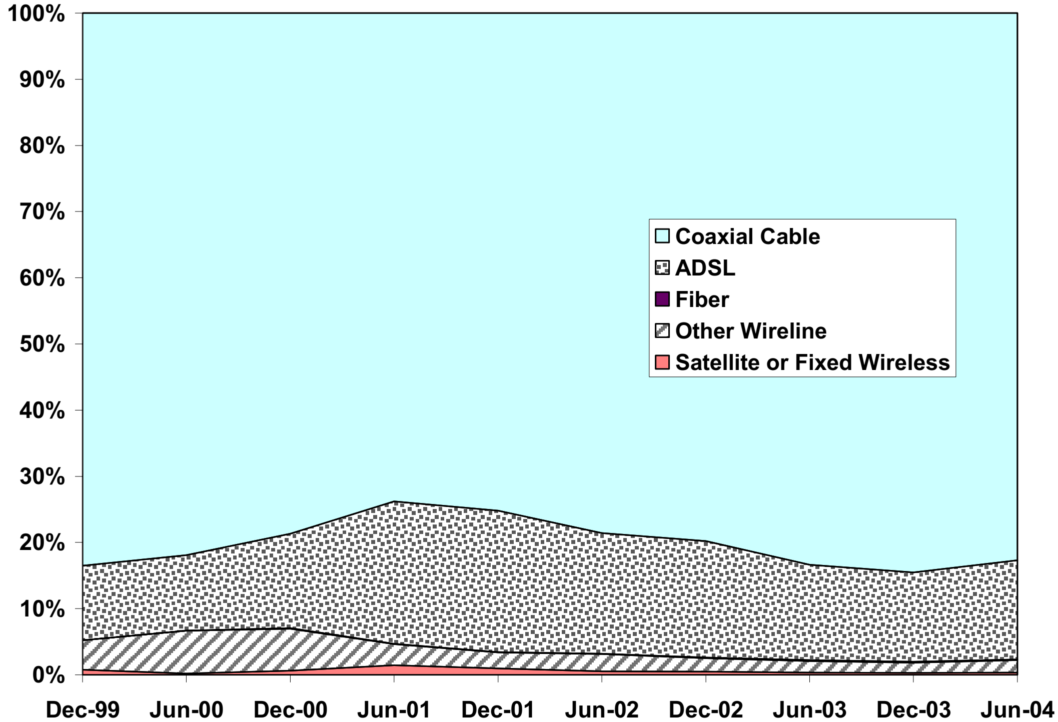

Figure 1.3: Percent of Residential and Small Business Advanced Services Lines

Fiber to the end user would provide the potential for greater bandwidth. Higher bandwidth opens the door to new applications that are not possible today, such as telemedicine, telepresence, and video teleconferencing. Fiber has the potential to be future proof; its electronics and optical components can be upgraded into the foreseeable future for greater bandwidth, instead of having to run new cable.

Initial attempts to deploy fiber to residenti[illegible] except when it doesn't work that way. [illegible]d States in 1989. Currently deployment is still not widespread, though there are many more trials underway. Widespread fiber-to-the-home deployment has suffered in part due to competition from lower-speed, cheaper, easier-to-deploy technologies such as DSL and cable modems.

Broadband providers have discovered that the user market that they had envisioned for their service hasn't materialized to an extent to keep them all viable. Excite@home, the cable modem Internet provider with the largest subscriber base at the time (approximately 3.7 million customers in the United States and Canada) filed for bankruptcy in September 2001. Even incumbent telephone and cable operators are not immune to the financial troubles.

In addition to broadband service offered by traditional carriers such as cable and telephone companies, non-profit efforts to provide broadband also play an important role. Several communities have started initiatives to provide more bandwidth, including fiber-to-the-home, to their areas.

In the state of Washington, Grant County wanted more bandwidth than was available in their area. In 2000, the Grant County Public Utility District began a six year build plan for a fiber-to-the-home network (Grant County Public Utility District, 2004). ~~Twenty one~~ Internet service providers currently offer service over the network. ~~Due to~~ state of Washington law, the

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Public Utility District cannot be a service provider and must serve as a wholesaler of the network.

The city of Palo Alto, California already had a broadband cable modem provider and access to digital subscriber lines (DSL), yet wanted more bandwidth. Initial planning for the deployment of fiber-to-the-home began in 1998. The city has had a much more rocky experience with its fiber-to-the-home deployment attempts than Grant County. The first Request for Proposals in 1999 to construct such a network in Palo Alto went virtually unanswered, the sole awk. ISP bidder subsequently went out of business. In December 2000, the plans were rearchitected and a trial network deployed by the local utility. In July 2004, the city council stalled plans to expand the network citing financial viability (D'Agostino, 2004).

Many companies that provide broadband services have experienced financial trouble. The technologies involved are uncertain and changing rapidly. The deployment of DSL rapidly eclipsed ISDN deployment, and ISDN is falling out of use. Bi-directional broadband satellite systems were proposed in 1995 but none of the fourteen systems that filed applications with the FCC have materialized. Many service providers and analysts think that fiber will eventually dominate the "last mile," such that DSL and cable modems are interim solutions. However, they recognize a "chicken and egg" phenomenon ~~with respect to~~ fiber deployment and applications awk^2 requiring fiber-enabled speeds. The demand by applications for bandwidth continues to grow, and some communities are venturing into broadband deployment to provide service in their area.

There are many issues surrounding the supply and demand of broadband that interact on many different levels. The research explores the forces at work and the conditions needed for further deployment.

1.2 Key Questions

The key questions the research proposes to answer are:

- What are the key policy factors that influence FTTH deployment? The research considers alternatives in both public and industrial policy.
- What changes to telecommunications policies might facilitate more rapid and successful FTTH deployment? The research explores current policy and how it influences deployment of fiber-to-the-home. Alternate policies and their effects on deployment are explored in an effort to contribute to the FCC's discussions on high speed Internet service.
- What technologies and roll-out strategies are best for a given set of circumstances? The research examines how different technologies and deployment strategies can be used to effectively deploy fiber-to-the-home in a way that will encourage adoption by users.

1.3 Method

Fiber-to-the-home deployment occurs within the context of the Internet, where technical, regulatory, economic, and social issues intertwine. The interactions between the many forces and players involved in fiber-to-the-home deployment are not currently well understood. The issues surrounding such a deployment are explored through a system dynamics model. The goal of the model is to assist with the assessment of deployment options by the various players such as communities, regulators, components companies, etc., and to help them understand the interactions involved in making deployment decisions.

The research draws from systems engineering, technology strategy, and policy analysis. To develop a reasonable model, technical knowledge of the characteristics and limitations of the technologies available has to be combined with business strategy knowledge and characteristics of user adoption. Policies that govern the deployment of broadband technologies are also taken into account, along with the notion of how policies could be modified or implemented to facilitate deployment.

The model includes consideration of the key players and interactions involved in the supply and demand of bandwidth. Key players include: the telecommunications industry, the user community, and regulators. These players interact to shape the market for broadband Internet services.

The telecommunications industry includes a wide range of component, system, and service suppliers. The cost of providing the service, including the cost of the necessary components and infrastructure, is included as part of the model. This portion of the model addresses ~~such factors~~ as cost of components and systems, cost of fiber deployment, the capability of the industry to provide the technology, the demand for the technology, and prices likely to arise in the respective markets.

Users are affected by both the price and the availability of service. To explore user demand, information on prices and Internet adoption rates is included. The growth rate of Internet users vs. the growth rate of broadband is explored, accounting for those geographical areas where broadband is not available.

Regulators are responsible for policies that affect everything from the cost to provide service to how competition will evolve. The portion of the model dealing with public policy assesses the effects of various policies on prices, deployment, and adoption rates.

System dynamics modeling was chosen as a methodology for the analysis because one of its key features is the ability to explore "what if" scenarios and complex interactions, such as analyzing the effects of new developments like "killer" applications, or large jumps in cost reduction. A system dynamics model is a simplified version of the real world. Through the use of graphical tools for implementing differential equations, system dynamics models attempt to capture key behaviors that are observed in real world systems. They allow the modeler to see what structures in the real world might cause an observed behavior: adoption rates are observed to increase, what is causing it? The model also allows the observation of what types of behaviors a structure in the real world can produce: how can adoption rates be made to increase or decrease? This information is useful in analyzing how public policy changes could influence user adoption.

Much of the information required to develop such a model is available in published reports. Annual demographic data for the United States are available that include the number of Internet users, the availability of broadband technologies, and availability of phone service/dialup Internet service.

Effects of current telecommunications policies have been explored by the FCC. The FCC also collects comments from interested parties, some of which also explore potential effects of proposed policies on the market.

The telecommunications industry tracks component prices and volumes. These are documented in industry publications, which address technology issues and also attempt to address consumer demand. Many equipment vendors publish pricing information in print catalogs and on the Internet. The FCC also tracks the deployment of telecommunications infrastructure in various reports.

Despite all the data available, there have been no attempts to combine it all into a comprehensive model of fiber-to-the-home deployment.

1.4 Model Overview

As described earlier, the broadband customer base is growing. Along with this growth, many communities are beginning to deploy fiber-to-the-home in conjunction with public utilities. The majority of these communities do not currently have broadband and are afraid of being left [illegible]y telecommunications companies that decide there is no business case for deployment in [illegible]munity. A high-level view of the dynamics driving this growth is in Figure 1.4. Plus signs on arrows connecting the factors in the diagram mean that an increase or decrease of the first factor results in a change in the same direction of the second factor. For example, as the broadband customer base increases, the available content and applications for broadband users also increases, or as the broadband customer base decreases, the available content and applications for broadband users also decreases.

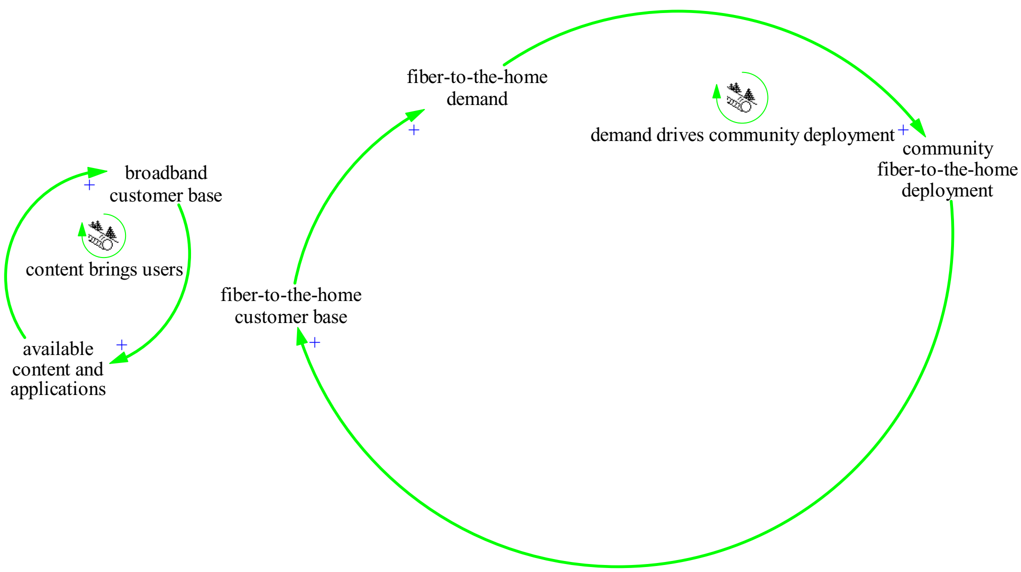

Figure 1.4: “Community Deployment” and “Individual User Demand”

The two loops shown in the diagram are called positive, or reinforcing, loops. Loops are labeled as balancing or reinforcing depending on how a change in one variable changes that same variable after going around the loop. If a change in the variable results in the same change of that variable after going around the loop, the loop is a reinforcing loop. If a change in the variable results in the opposite change in that variable once going around the loop, that loop is a balancing loop. For example, a reinforcing loop shown in the diagram shows an increase in fiber-to-the-home demand results in an increase in community fiber-to-the-home deployment which increases the fiber-to-the-home customer base, which ultimately increases demand for fiber-to-the-home. A balancing loop would show an increase in fiber-to-the-home demand resulting in a decrease in fiber-to-the-home demand after going around the factors in the loop.

Figure 1.5 shows an additional loop, called the “cost drives community deployment” loop. Components and system companies are hoping that community deployments will result in sufficient volume to spur further FTTH technology development. This development in turn would cause the costs of FTTH deployment to go down. The minus sign on the connecting arrow between "FTTH technology innovation and cost reduction" and "cost to provide FTTH service" implies that change in one factor results in the opposite change in the other factor (i.e., increases in technology innovation result in decreases in cost).

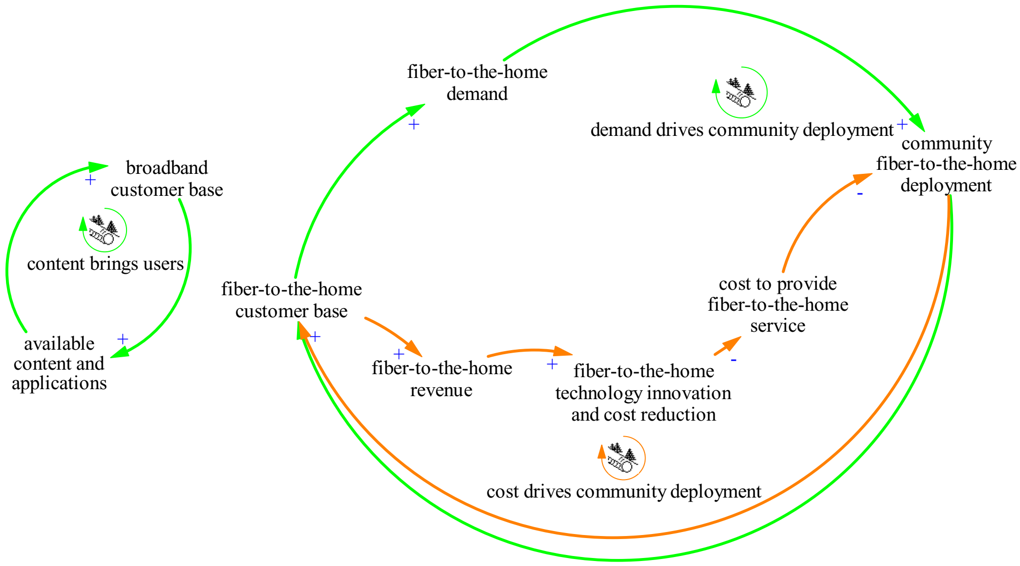

Figure 1.5: Emerging "Cost Reduction" Loop

Figure 1.6 adds the "community network externalities" loop to the diagram. This loop captures the idea that as more and more individuals have broadband, demand for broadband in communities that do not have broadband rises. Since many of these communities are choosing to deploy fiber rather than other forms of broadband, this demand translates into community demand for FTTH. As more communities deploy FTTH the broadband customer base increases, thereby increasing the network externality effect. This is a reinforcing loop.

Proponents of FTTH deployment hope that the cost reduction and demand generated by the "cost reduction" and "community network externalities" loops of Figure 1.5 and Figure 1.6 are sufficient to provide a business case for commercial deployment of FTTH as shown in Figure 1.7. The sheer cost of deploying FTTH is the reason most cited by telecommunications companies for not pursuing FTTH deployment. Once commercial deployment begins, the system generates more revenue and further cost reduction, ~~thereby~~ continuing the deployment trend.

Once cost reduction allows a viable business case for commercial FTTH deployment, the "commercial network externalities" loop shown in Figure 1.8 will continue to drive the system. As seen in Figure 1.8, all loops at the high level of this system are reinforcing loops. Thus, once all of the loops become active the system will continue to grow and feed on itself until adoption saturates. The expected trend is similar to that seen in other telecommunications technologies (e.g. fax machines and telephones). To date, commercial deployments by telecommunications companies have not been a reality. The difficulty in this system is the transition from community deployments to wider-scale commercial deployments.

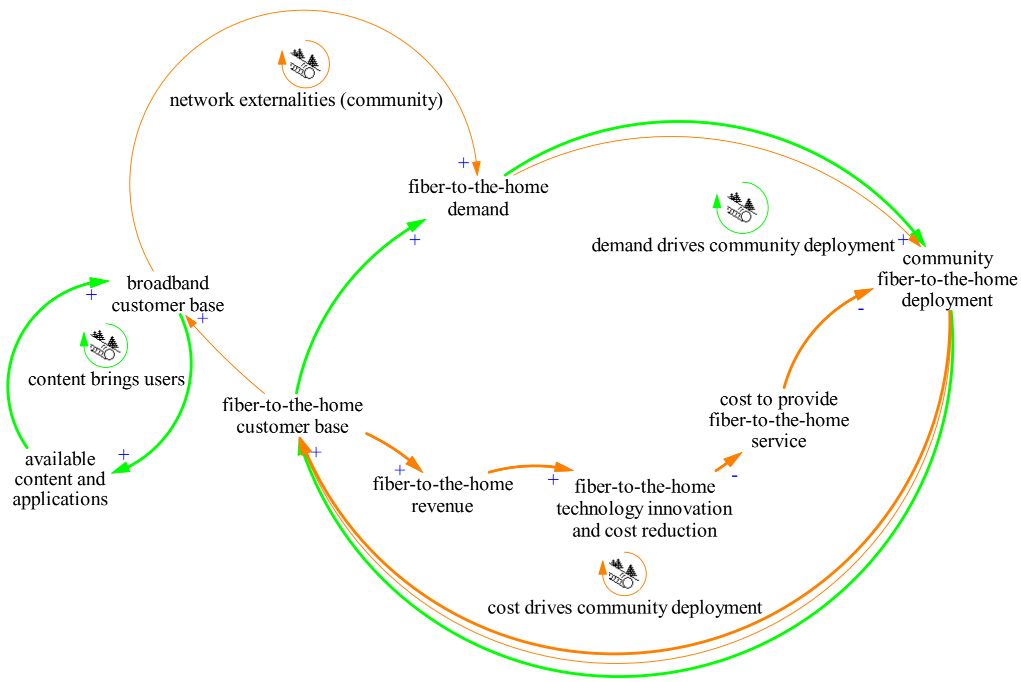

Figure 1.6: Emerging "Community Network Externalities" Loop

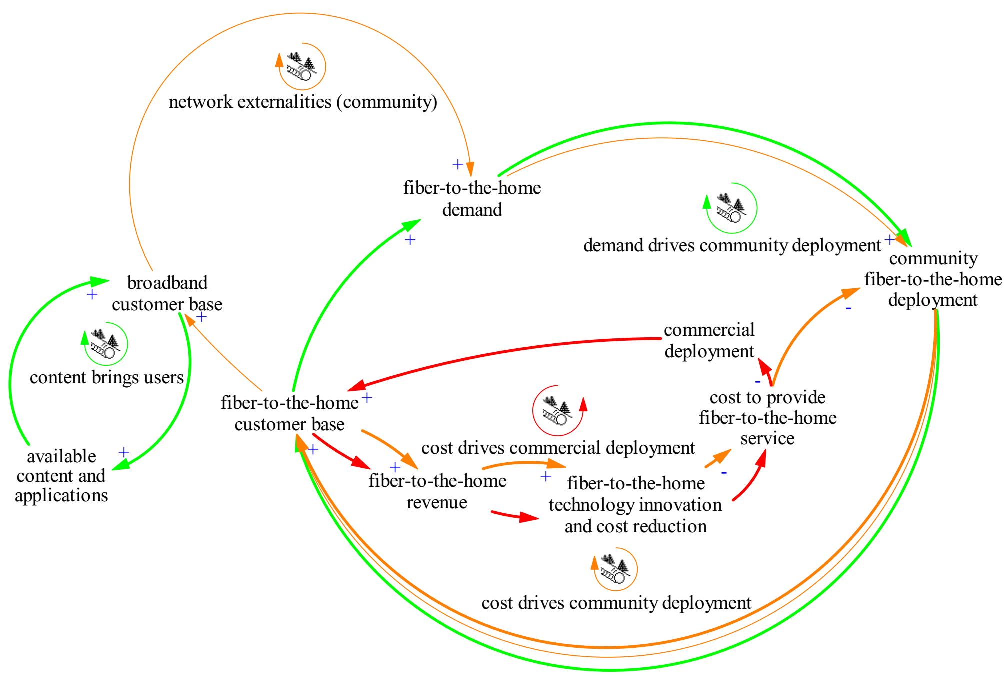

Figure 1.7: "Cost Reduction Drives Commercial Deployment" Inactive Loop

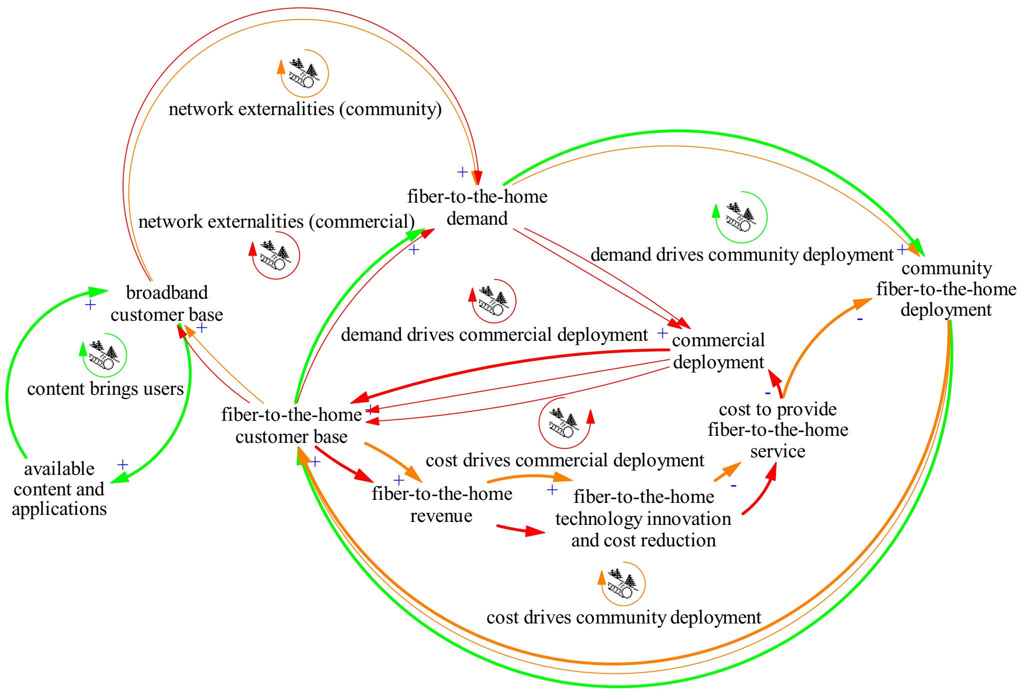

Figure 1.8: High-Level System Dynamics Fiber-to-the-Home Model

1.5 Regulation

Regulation is a key factor that could cause community deployments to happen more rapidly and commercial deployments to become. Regulation does not have its own variable at the high-level of Figure 1.8 because regulation may have an effect anywhere and everywhere in this system.

Regulation can have a profound effect on how the deployment of fiber-to-the-home progresses and on how many competitors participate in any given region. The FCC has been monitoring the deployment of broadband and the investment in broadband infrastructure to determine if, when, and how regulation may be appropriate. Opponents of regulation believe that if regulations are put in place that require facilities providers to share infrastructure with competitors, the facilities providers will be less likely to invest in upgrading equipment. Proponents of regulation believe that forcing the sharing of infrastructure is the only way to ensure that the consumer will have a choice of providers and a choice of services.

Regulation is capable of having a profound effect on how FTTH is deployed. To incorporate these effects into the model, various regulatory are developed and included in the model runs.

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