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An Investigation of the In-Home Networking Industry

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1 Introduction

The purpose of this paper is to trace the emergence and evolution of the home networking industry (HNI) from its origins to its current position as an integral part of the modern computing experience. We then identify emerging trends that will shape the HNI industry in the years to come.

HNI is a rapidly evolving industry, which, over the course of its 20 year history, has been profoundly affected by the rapid rate of technological advancement. Through an analysis of the technology S-curves, complementary assets and network externalities, we identify conditions and events that changed the industry in the past.

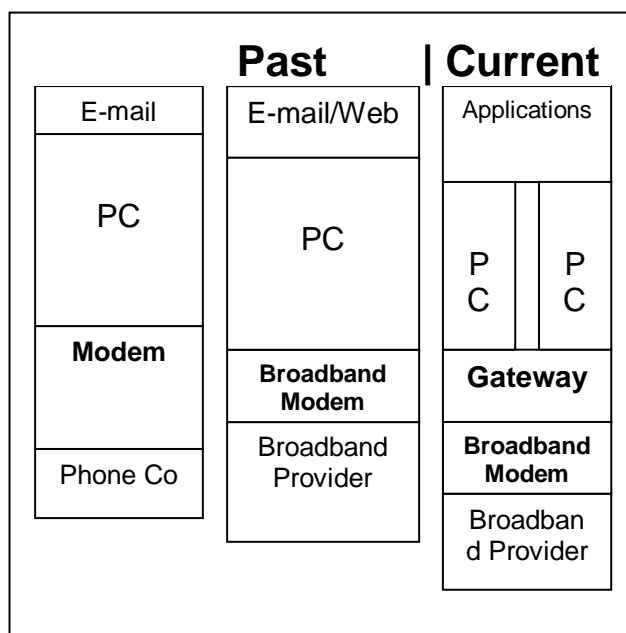
We conclude by applying this analysis to develop one plausible outcome for the future of the HNI. In this outcome, we envision a fully interconnected home network whereby consumers share, consume and store media across numerous devices. Moreover, the devices themselves interact with each other, leading to a diverse range of applications which will run across the home network.

2 Industry Description

As used in this paper, the HNI refers to the communications infrastructure stack that enables consumer applications, such as e-mail, web, etc, to connect to each other and to the outside world. This infrastructure includes multiple companies and segments:

- **Communications providers:** Comcast, Verizon;
- **Modems:** 3Com, Motorola;
- **Gateways:** D-Link, Linksys;
- **PCs:** Intel, Microsoft.

Below is a view of both the stack and its evolution over time:



Early in its life, the HNI was measured on its data communications rate: 300 baud modems running over POTS phone lines; 9600 baud modems; 128k ISDN on phone lines; 1Mbit and rising on DSL; 1.5Mbit and rising on cable modems; and various speeds on metropolitan wireless systems. Even with the radically changing interface standards and dominant players (the transition to broadband modems left all of the POTS modem manufacturers behind), one constant remained: until approximately 2000, data flowed into the house, through a modem and then directly to a PC.

Later, with the introduction of broadband communications, the HNI changed markedly. Existing broadband modem manufacturers remained fixed as households installed multiple computers and a market for gateways blossomed. A raft of new companies, including Linksys, D-link and NetGear, were formed to exploit this new market.

3 Analysis of the Past and Current Situation

3.1 S-Curves

We have sketched S-curves to identify where disruption has occurred previously in the industry and to suggest how future S-curves might evolve.

The in-home networking industry has progressed through two major disruptions that have changed the performance metrics and created new opportunities for technology vendors. We list these phases in chronological order of disruptions as they have historically occurred. These phases are termed: “pipeline” and “gateway” to describe the major performance metric that govern their use.

Pipeline: Technology vendors compete to deliver bandwidth to the end user. The key performance metric is bits per second to the home.

Gateway: Vendors compete to provide network services to distribute and share the bandwidth from the primary access point to devices within the home. The key performance metric is the number of connections/ports available for sharing.

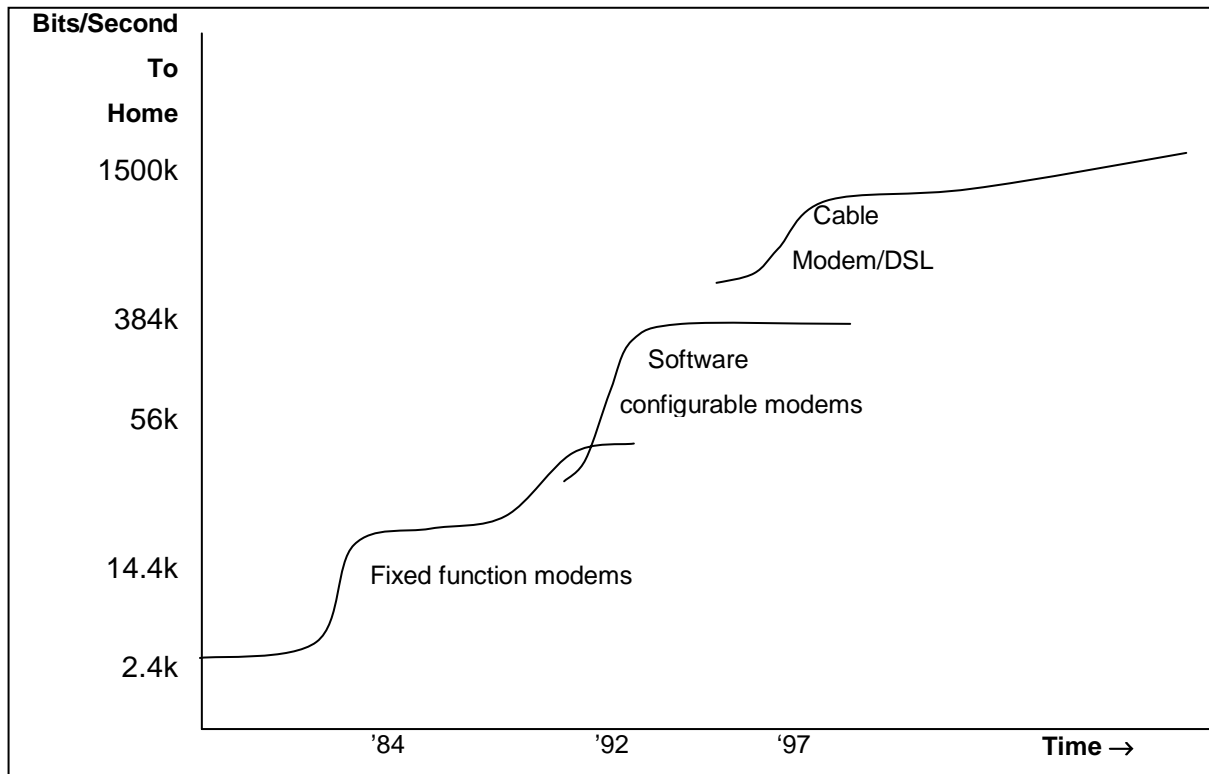
3.1.1 Pipeline Phase

There are three discontinuities that characterize the Pipeline phase of home networking.

Fixed function or hardware modems: standards are slow moving, so modems fix functionality in hardware.

Software configurable modems: the hardware evolved to be configurable, enabling standards to evolve quickly; updates kept consumers “up to speed”.

Cable Modem/DSL: Data moves out of the voice band and its 56kb/s limit, and up to MHz range, enabling much higher throughput.



Firms in this industry followed a familiar pattern: Technological innovation drives a unique solution that enables first-mover advantage. Hayes and USRobotics were early leaders in this phase of the industry. These firms leveraged their technological uniqueness (greater performance) to build strong brands and excellent retail distribution allowing them to create and capture value for many years. They also led the discontinuity from fixed-function to configurable modems. As the market matured and the rate of innovation slowed, standardization occurred and the technology became commoditized. Even these branded players were unable to capture significant value.

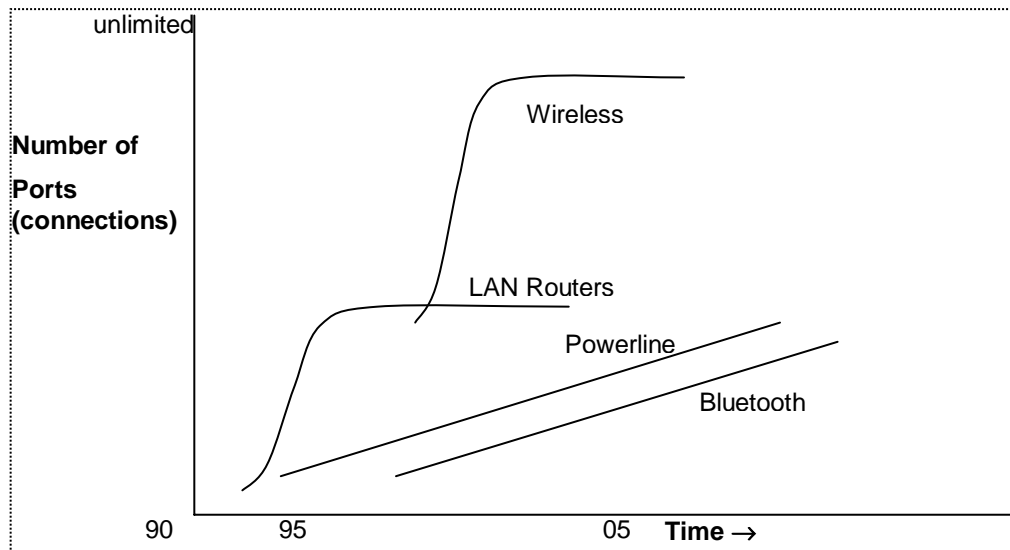
The previous leaders in the industry fell because the discontinuity from modems to cable-modems also included a shift from consumers-as-purchasers to service-provider-as-purchaser (Verizon, Comcast). Other firms, such as Motorola and Toshiba, who were much better positioned to sell to large service providers, took over the nascent cable modem/DSL market.

3.1.2 Gateway Phase

As shown in the figure below, there are two discontinuities that characterize the Gateway phase of home networking:

Wired: Ethernet is the dominant standard for downstream (PC) connections. The metric is number of ports.

Wireless: WiFi (802.11a/b/g) is the dominant standard for downstream (PC) connections. Although the data rates increase quickly, the primary metric is still number of ports (connections).



Connection speed is no longer the primary driver of the industry because bandwidth has outstripped users needs. The upstream data connection provides data at 1-3Mb/s, which makes it the slowest/weakest link in the communications chain. Now, although the cost of 100Mb Ethernet home networking gear is on par with the vastly slower 802.11a/b/g wireless networking equipment, most homes are installing the slower wireless equipment. While wired LAN routers could service multiple PCs, wireless routers can service an almost infinite number of potential devices. For a small premium, users get nearly unlimited expandability and mobility with no *effective* loss in communication speed.

3.2 Network Effects

3.2.1 Pipeline

In the Pipeline phase, standardization was crucial because each service provider faced thousands or millions of consumers dialing into modem banks and the providers did not want to support thousands or millions of separate communications protocols. As such, the network effects were extremely strong, preventing the entry of new standards unless the entire market shifted.

US Robotics took a “standards-plus” approach with their Courier HST modem, which provided non-standard 9600bps and, later, 14400bps in an era of 2400bps modems. At \$500, however, they drew in corporations with high point-to-point communications needs, which did not excite a network effect. USR probably made high-margins and not high-volumes on the HST products.

When the pipeline began its shift to broadband modems, network effects played very little effect. Since a consumer that purchased broadband service from Comcast was sent a modem selected by Comcast, there was little benefit to a consumer if another consumer used a similar modem or network. Later,

consumers indirectly felt the benefits of the DOCSIS¹ cable modem standard as mergers rolled across the industry and providers were able to quickly integrate their acquisitions standardized networks.

3.2.2 Gateway

By its very nature, the gateway is a standards² driven hub for communicating packets between an upstream standardized Ethernet port on the broadband modem and downstream standardized Ethernet/WiFi ports on PCs. As a result, few vendor-specific network effects are present.

With the introduction of wireless functionality to gateways, manufacturers attempted to excite localized network effects within the home by following a standards-plus approach: each manufacturer's gateway was WiFi compatible, but consumers could have substantially higher communications rates in the home if their wireless communications cards were also made by the same manufacturer. This approach appeals largely to lead users and might drive incremental sales; it would not excite larger network externalities and drive all purchases to a single vendor.

3.3 Uniqueness versus Complementary Assets

3.3.1 Pipeline Phase

Companies initially innovated in performance (USRobotics 9600 baud modem) and in features (internal modems, fax-modem). However, as mentioned above, the requirements for standardization were so powerful that consumers would not purchase a feature that jeopardized standardization.

With a slightly differentiated, commodity product, providers of home networking equipment then developed the complementary assets of recognizable brands (US Robotics charged a premium over white-box modems), sales relationships (USRobotics built a successful corporate accounts channel) and distribution network to capture value in the industry.

The above comment remained true for the broadband modems providers, too. They had to follow rigid standards and their primary asset was their ability to handle very large accounts, such as Comcast and Verizon.

3.3.2 Gateway Phase

The Gateway phase ushered in an era of ferment. Here, consumers cared about standards, but now they also cared about a number of other unique features, which allowed companies to differentiate their products. Some "gateways" were simply routers, some included a firewall, some included a cable/DSL-modem and

¹DOCSIS is the Data Over Cable Service Interface Specification and provides the communications standard for all cable modems.

²A gateway must implement standard communications protocols, such as TCP/IP, Ethernet and Wifi.

some included print server functionality. There was much room for unique products, but the uniqueness would not last long.

A dominant design, in the form of a wired/wireless gateway with firewall and NAT³, emerged and drove most gateway vendors to supply a product which embodied the dominant design. Although there were still many unique features that could be added, the vast majority of devices sold fit into the dominant design. Also, much of the enhanced functionality was software controlled, so any must-have feature that was implemented on Linksys' gateway product was soon implemented on D-Link's product and vice versa.

Without much in the way of uniqueness to pull customers onto a company's product platform, complementary assets were the primary driver of market success: products are sold through giant electronics retailers where only those with retailing expertise survived. Furthermore, these products are confusing, so consumers (even computer-savvy Sloanes) use brand to guide purchases and will likely replace out-of-date gear with the same brand (installed base).

The shift to wireless offered a brief window of uniqueness to vendors because they could add wireless and get consumers on the upgrade treadmill from 802.11 to 802.11b to 802.11a/g. Since most manufacturing and design is outsourced, this window closed quickly as all vendors had access to the same technology. However, wireless connectivity is a particularly difficult function to "get right", so the value of a good brand further increased as consumers sought not only a product with all of the features but also one that they could get to work correctly in their system.

³ NAT stands for Network Address Translation and is a technology for allowing multiple downstream computers to share a single upstream IP address.

4 Predictions for the Future

4.1 Scenario Analysis

The future of the HNI is heavily influenced by two major trends that drive industry performance and value creation:

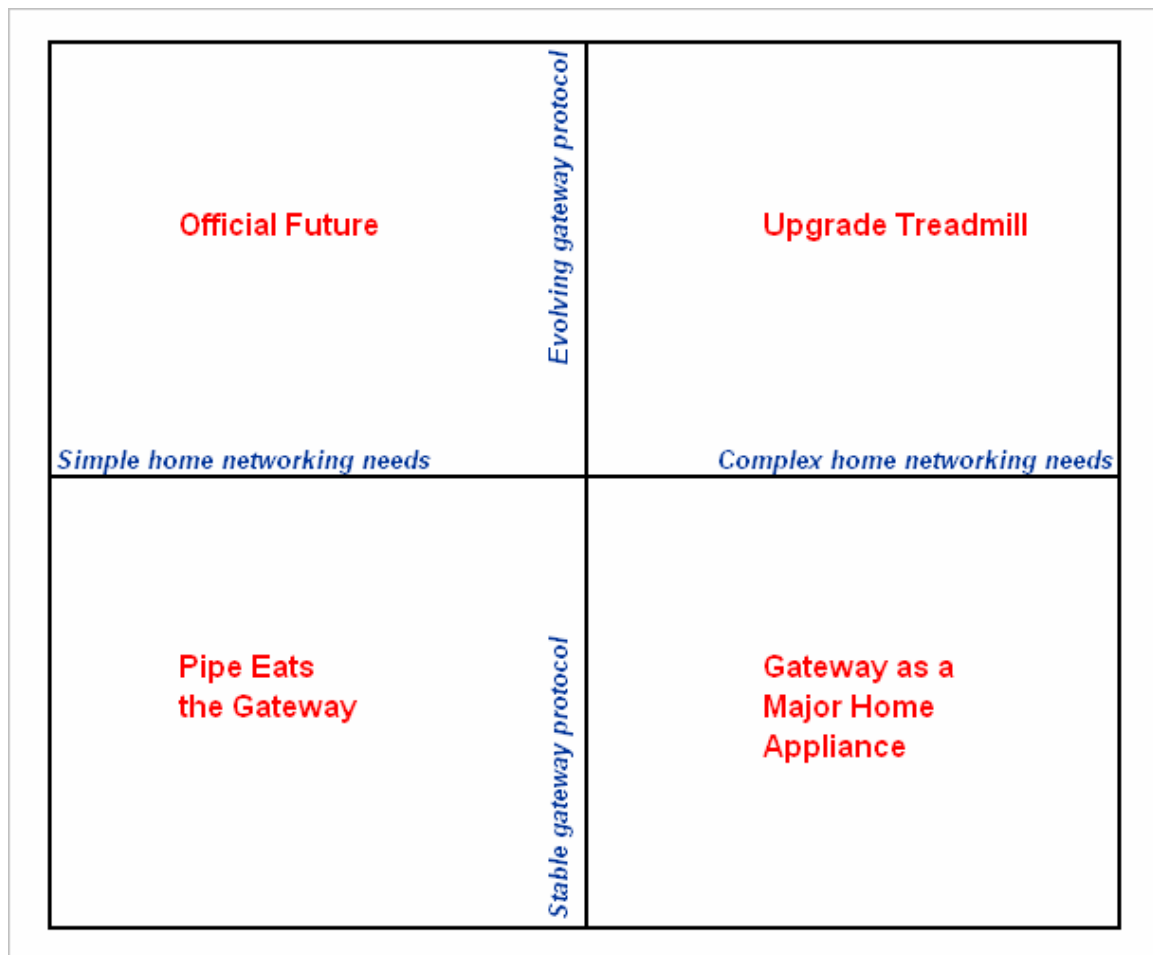
a) The complexity of the home network

This refers to the number of connected devices on the network. In the “complex” scenario, consumers continue to add network nodes such as additional computers, laptops, printers, external hard-drives, TV’s (or media centers), stereo systems and perhaps even toasters. In the “simple” scenario home networks do not grow much beyond the current nodes (PC and printer).

b) The innovation of gateway protocols

This refers to the stability of gateway protocols. In the “rapidly evolving” protocol world, in-home delivery standards continue to improve and multiply. An example of constant improvement is the evolution from Ethernet to Wi-Fi (as well as the individual improvements within these categories from 10Mbps to 100Mbps). Additionally, new protocols for in-home bandwidth delivery, such as blue-tooth and household wiring, will fuel an evolving multi-standard environment that favors the gateway providers. In the “stable” world, these protocols stabilize and devices standardize in a single delivery platform.

Scenario Analysis for In-Home Networking Vendors



These two forces provide 4 plausible scenarios that we can foresee:

4.1.1 Official Future

Home networking needs turn out to be relatively simple; typically a computer, printer and laptop connected via a gateway device. However, the rapid cycle of gateway protocol innovation continues and consumers continue to upgrade home connections for speed and quality. In this world, incumbents with existing devices and established brands have the potential to dominate the marketplace through a fast follower strategy and complimentary assets of brand and distribution.

4.1.2 Pipe Eats Gateway

In a world where protocol innovation slows and home networks do not grow beyond their existing size, the pipeline vendors (Comcast, TimeWarner and Verizon) will integrate gateway functionality into their connection points. Set-top boxes, cable modems and DSL connections will consume the gateway, relegating these vendors to the "Caller ID" appliance manufacturers in the telephone space. Gone.

4.1.3 Upgrade Treadmill

Home networking devices proliferate and the number of interconnected devices rapidly increases. Home networking nodes are likely to include TV's, telephone service, computers, printers, music devices (iPods, stereos) and home monitoring devices (cameras, alarms etc.). Additionally, the gateway protocols proliferate to include Wi-Fi, Wi-Max, blue-tooth and others. In this scenario, the gateway plays a critical role in connecting disparate devices and consumers are constantly upgrading devices to keep pace with new functionality.

While this scenario may present promising revenue opportunities through an established upgrade path, there is a potential downside to this "ferment" quadrant: incumbents might be open to disruptive innovation that can displace their existing brands and market leadership.

4.1.4 Gateway as a Home Appliance

In this world, home network devices proliferate while the gateway protocol remains stable. The gateway serves as a "platform" to connect disparate devices that must all conform to a defined protocol standard. Incumbents will be able to leverage existing complimentary assets in branding and distribution to capture significant value as a platform appliance into which other devices connect.

4.2 A Scenario Prediction

Now that the possible scenarios have been outlined, we predict which scenario may be the most likely to occur: Gateway as Home Appliance.

This is predicated on the following assumptions about the future:

1. Home networking protocols will continue to evolve in an incremental fashion.
2. A rise in home networking applications will drive the need for a complex multi-node network.

The intersection of these two driving forces, squarely describes the lower-right portion of the scenario analysis.

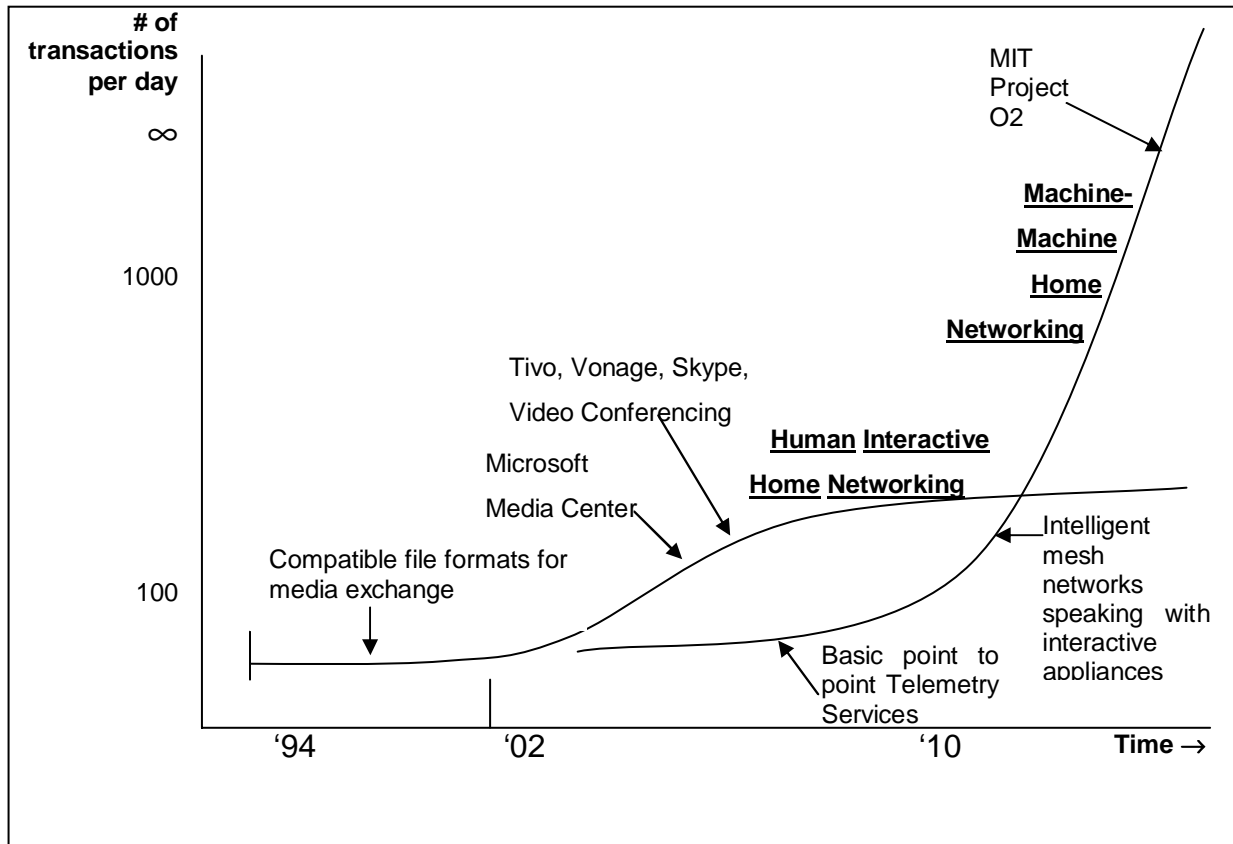
4.2.1 Home Networking Protocols

While we believe there is always room for continuous protocol improvements, we foresee current implementations as sufficient for consumer home networking needs. Bandwidth bottlenecks typically occur in the pipeline to the home rather than inside the home network. Traditionally, in-home protocols have vastly exceeded external bandwidth performance and we believe this will continue in the future.

4.2.2 Complex Home Networks

We predict that end-user applications are the driving force for more complex home networks. This development will give rise to a new performance metric for gateway providers: the number of "transactions" inside the home network.

As shown in the figure below, we expect there to be two S-Curves within this new metric. The first we label Human Interactive Home Networking (HIHN), which is starting to evolve at present in the form of intelligent multimedia electronics. The second S-curve will be Machine to Machine Home Networking (MMHN), which will take off as home networking becomes pervasive and allows for the intelligent house.



Human Interactive Home Networking

In the HIHN curve, distinct transactions for digital content are requested by a human. VoIP, interactive gaming with local computer terminals and video and audio content sharing all contribute to the shape and scale of this curve. This curve peaks at approximately 100 transactions, a reasonable number of web sessions, songs, movies, videos, TV shows, etc, to be consumed in one day.

Firms driving the HIHN phase of in-home networking have for the most part done an excellent job creating and capturing value. For example, Tivo and Vonage have, in a short period of time, captured significant value from both the television and telephone industries.

Machine to Machine Home Networking

MMHN plots the projected growth of in-home network use by machines as they interact with each other. An alarm clock instructing the coffee maker and toaster to prepare breakfast are examples of interactions that compose this curve. This aspect of in home networking is in such an early stage that we did not attempt to forecast when and at what level of transactions per day this curve will level out.

HIHN is just beginning to move from “ferment” to “take-off” stage of development. Startups such as Ember Systems and Smart Dust who have developed home networking technologies which have great promise but as adoption is still very slow, it is too early to make significant predictions about dominant design.

4.2.3 Home Networking Impact

The impact of this application revolution will be the increased number of home networking nodes and a stronger need for a gateway platform to connect all these devices. At the same time, gateway protocols will standardize on a few public and open standards.

As a result, Gateway providers will have an opportunity to create a “platform” business that interconnects disparate nodes on the network. Vendors will differentiate products based on functionality and quality, especially as applications become more complex.

5 Conclusion

The home networking industry (HNI) has provided an interesting test bed for some of the frameworks and ideas from Technology Strategy. In particular, we used the differing viewpoints of S-Curves, network effects and “Uniqueness versus Complementary Assets” to analyze the past behaviour⁴ of the HNI market.

From the above analysis, we developed four different scenarios and concluded that the network communications will stabilize while applications continue to diversify. This scenario provides a risky environment for the HNI companies to grow their piece of the home networking pie: consumers no longer ride the upgrade treadmill, but new applications provide opportunities for growth.

The major pitfall in this scenario is that large players in the upstream (communications provider) and downstream (PC) portions of the value chain are eager for incremental revenue, so might squeeze the HNI industry down to marginal functionality and, in the ensuing commodity market, marginal cost. When the market is large enough, the communications providers could include wireless networking and firewall functionality in the modem. Downstream application companies, such as Intel and Microsoft, have made a point of aggressively incorporating and commoditizing the functionality required by any application, thereby minimizing the need for gateway manufacturers to add the functionality.

Although the HNI faces substantial risks of commoditization, HNI participants with strong technological and strategic skills should be able to identify new applications to be incorporated into the gateway, thereby growing both their industry and their piece of the industry's pie.

⁴ Note: the English spelling of “behaviour” is used to excite the student-professor network effect in which adopting a common, comfortable language/spelling leads to increased comprehensibility and grade-ability.