

Research on the Contractual Characteristics of Internet Architecture Postprint

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Abstract

Research on network architecture is a technical issue, but more fundamentally, one that impacts economic development. Architecture can be regarded as the material foundation for designing contracts that govern the distribution of interests among communication participants. Based on Internet architecture, this paper discusses how opening edge networks to users and increasing autonomy can promote the development of the network economy. This paper employs analytical tools from institutional economics—transaction cost economics and contract economics—to analyze contracts derived from architecture, thereby helping us understand the microeconomic significance of architecture with macro-level characteristics. While further expanding the user base, it is imperative to systematically investigate the factors within network architecture that constrain the development of the network economy. We argue that: adopting the bilateral governance proposed by Williamson[?] as the principle for contract design, increasing edge network autonomy under existing technologies can drive the emergence of a market for outsourcing emerging information services. The Internet of Things represents one vehicle for this market. Under contracts built upon this foundation, users gain greater freedom in selecting information services and IT equipment; simultaneously, network access providers can reprice their specific assets by offering virtual networks. We propose an open edge network architecture—IPVN—and based on this structure, present a service delivery model that serves human settlement needs.

Full Text

A Study on the Contractual Characteristics of Internet Architecture

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Abstract: Research on network architecture is a technical issue, but more importantly, it is an issue that affects economic development. Architecture can be viewed as the material foundation that constrains the design of interest distribution contracts among communication participants. Based on Internet architecture, this paper discusses the role of opening end networks to users and increasing autonomy in promoting the development of the network economy. Using analytical tools from institutional economics—transaction cost economics and contract economics—this paper analyzes the contracts derived from architecture, helping us understand the microeconomic significance of architectures with macro-level characteristics. While further expanding user scale, we must systematically study the factors in network architecture that constrain network economic development.

We argue that: using the bilateral governance principle proposed by Williamson as the basis for contract design, under existing technology, increasing end-network autonomy can drive the emergence of emerging information service outsourcing markets. The Internet of Things is one carrier of this market. Under this contractual framework, users have greater freedom in selecting information services and information equipment; simultaneously, network access providers can reprice their specific assets by providing virtual networks. We propose an end-network-open architecture—IPVN—and based on this structure, present a service delivery model that serves human living needs.

Keywords: Network Architecture, IPVN, Institutional Economics, Bilateral Governance

July 2009: Two Contradictory Articles

In July 2009, two opposing articles once again pushed the future of the network economy to a crossroads of “death” versus “vitality.” One was titled *The Internet Is Dead (as an Investment)* [11], authored by James Altucher, managing partner of hedge fund management company Formula Capital and a columnist for media outlets such as the *Financial Times* and *The Wall Street Journal*. The other was titled *The Internet Is Alive and Well (as an Investment)* [17], authored by Fred Wilson, co-founder of Union Square Ventures, a venture capital firm that invested in Twitter.

The development trend of the Internet economy is not only a concern for investors, but also a shared concern for network practitioners, network technology researchers, economists, policymakers, and the broader public.

From an industrial perspective, the Internet is an unprecedentedly large trading system. In the complex network world, discussing the future of the Internet economy solely in terms of a specific technology, application, or company cannot present a clear development outline to people, nor is it representative. This paper attempts to use methods for analyzing contractual characteristics among traders in economic systems to understand the characteristics of the Internet economic system, and under the guidance of contractual relationships, to explore

potential transactions derived from network architecture and their impact on network economic development.

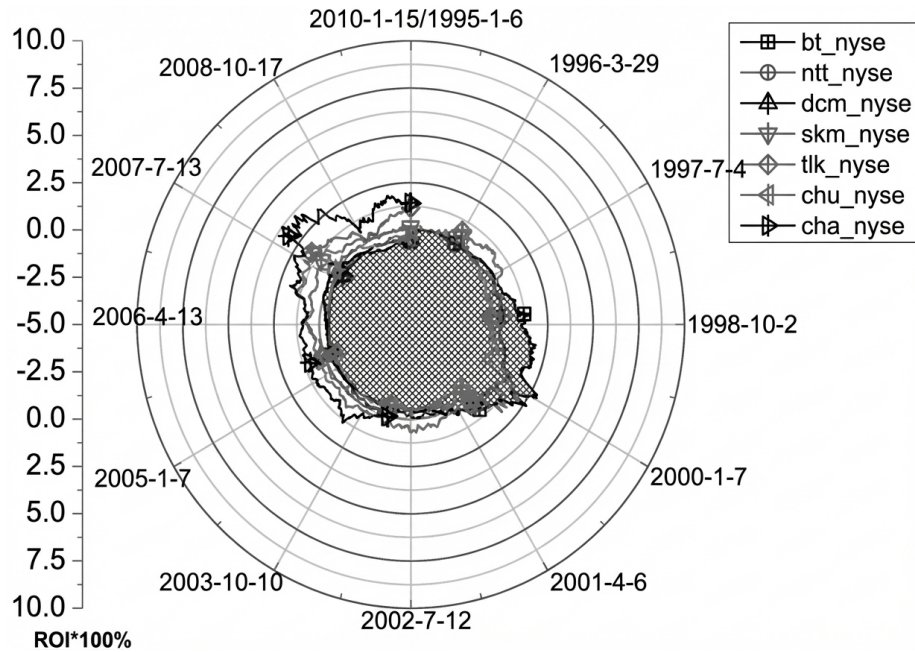


Figure 1: Figure 1

Exchanging information is the fundamental purpose for which people use communication networks, and we believe this is also the basic transaction content of the network economic system. In today's Internet-based trading environment, Internet architecture assigns different roles to participating traders: Internet Service Provider (ISP), Internet Content Provider (ICP), and general users (hereinafter referred to as "users"). General users can be individuals, units, organizations, or companies using the network.

The separation of service and bearer is the basic transaction model in the Internet. Simply put, users select needed information through websites of network content service providers; the specific information selected by users is then loaded onto electrical (or optical) signals, which are transmitted through the physical network of Internet service providers. In other words, content (service) and transmission (bearer) are provided by different service providers. Compared with telephone networks where service and bearer are bundled together, this transaction model enables content service providers to gradually gain control over information exchange during the process of providing matching services for information publishers and receivers.

The transaction model centered on information services can be viewed as a contractual relationship derived from the underlying network architecture. Based

on the above analysis, the relationships among participants in the Internet trading system are shown in Figure 1: users are information consumers, Internet service providers are data transmission service providers, and content service providers are information service providers. The contract between information consumers and data transmission service providers is a data transmission service contract; the contract between them and information service providers is an information service contract. The contract between information service providers and data transmission service providers is also a data transmission service contract.

Under this contractual framework, various technologies and services belong to both factor markets and product markets. Based on this contractual framework, this paper explores the interest distribution scheme of the network economic system determined by network architecture; simultaneously, on the basis of the existing Internet, this paper focuses on discussing the role of further opening end networks to users and increasing the degree of end-network self-governance in promoting network economic development.

The remainder of this paper is organized into four sections: Section 2 compares the stock trends of major network service providers in North America, Europe, and Asia from early 1995 to early 2010 (a 15-year period), as well as the stock trends of top global content service providers from early 1998 to early 2010 (a 12-year period). Using BT and Vodafone (VOD) on NASDAQ as representatives of network service providers, we conduct a horizontal comparison of investment return (ROI) historical trends with content service provider companies categorized by business type. Section 3 provides an in-depth analysis of the contractual relationships among network service providers, content service providers, and users in the Internet, and based on the interdependent demand curve [14], offers an economic explanation for the data in Section 2. From the perspective of institutional economics, we discuss the role of increasing end-network autonomy, proposing that changing the governance structure between network service providers and users to bilateral governance may greatly promote network economic development. Section 4 proposes a high-autonomy network architecture based on Network Address Translation (NAT) technology—IPVN (IP-based Virtual Network)—and analyzes its foundation, feasibility, and a multi-target virtualization service delivery model built on IPVN. Section 5 concludes.

2. Historical Investment Return Trends of Sample Stocks for Network Service Providers and Content Service Providers

The investment value of network stocks is the focal point of the debate between Altucher and Wilson. We believe that by comparing the historical development of stock trends, we can break free from the limitations of specific technologies and applications while comprehensively reflecting the economic effects of various

technologies and applications. Based on the role division of network architecture and using stock historical trends as the observation object, this paper compares the historical stock trends of major network service providers in North America, Europe, and Asia from early 1995 to early 2010 (a 15-year period), and the historical stock trends of top global content service providers from early 1998 to early 2010 (a 12-year period). Using BT, Vodafone, and Telefonica (TEF) as representatives of network service providers, we conduct horizontal comparisons with content service provider companies categorized by business type as a method for observing changes in network economic interest distribution.

2.1 Historical Investment Return Trends of Sample Stocks for Network Service Providers

The basic criteria for selecting network service provider company samples are: participation in network infrastructure construction in the early days of the Internet, major network deployment in economically developed or fast-growing regions, large market capitalization, high technological maturity, provision of fixed-line access services, and large number of access users, as shown in Table 1. By region, we categorize network service providers into North America, Europe, and Asia. For sample companies, we use historical stock data provided by Google Finance to analyze historical investment return trends. The ROI calculation method is:

$$\text{ROI} = (\text{Current Week Closing Price} - \text{Starting Week Closing Price}) \div \text{Starting Week Closing Price}$$

This method can reflect fluctuations in cumulative investment returns.

We use the week closing price on January 6, 1995 as the statistical starting point and January 15, 2010 as the ending point. During this period, network infrastructure construction experienced three stages: startup, growth, and stabilization. China Telecom and China Unicom have short listing histories, and their trends are listed only for reference, not for analysis. Figure 2 shows the historical investment return trends for investing in major European network service provider stocks. Figure 2(b) maps the data from Figure 2(a) to polar coordinates to generate the European network service provider investment return trend chart, where polar coordinate scales are merely time markers not proportional to time scales (approximately one year per 30 degrees). Based on the degree of overlap among the areas enclosed by each curve in polar coordinate space, we select BT (bt_nyse), Vodafone (vod_nasdaq), and Telefonica (tef_nyse) as representatives of network service providers, while using BT as the benchmark for cross-regional network service provider comparisons.

2.2 Historical Investment Return Trends of Sample Stocks for Content Service Providers

The basic criteria for selecting content service provider company samples are: business content, large market capitalization, long business development history,

and representativeness in the industry, as shown in Table 2 . We selected representative companies from three main content categories: e-commerce, search services, and news media. The above categorization does not indicate that these companies operate only single services. For sample companies, we use historical stock data provided by Google Finance to analyze historical investment return trends using the same calculation method.

We use the week closing price on January 2, 1998 as the statistical starting point and January 15, 2010 as the ending point. During this period, content service provider companies experienced the growth and stabilization stages of network infrastructure construction. We use the benchmark method to compare the stock trends of network service providers and content service providers. We select BT (bt_nyse), Vodafone (vod_nasdaq), and Telefonica (tef_nyse) as benchmarks for network service providers. As shown in Figure 2, all three have long development histories; secondly, the obvious differences in their return trends form a banded range, providing a reasonable reference range for comparing the relative strength of network service providers and content service providers. Figure 3 FIGURE:3 shows the historical investment return range for typical network service provider stocks. Figure 3(b) maps the data of e-commerce content service providers and typical network service providers to polar coordinates to generate the stock investment return trend chart.

2.3 Analysis of Sample Historical Trends

As shown in Figure 2, the trends of network service providers can be divided into three categories: Telefonica and US CenturyTel belong to the first category, able to reach new highs after the network bubble burst; Vodafone belongs to the second category: although the curve fluctuates significantly after the bubble burst, it never exceeds the previous peak; other telecom companies are concentrated in the third category: showing stable trends after the network bubble burst. It can be seen that the second and third category trends define the basic investment return value band for network service providers. We specifically define this value band using BT and Vodafone (VOD) on NASDAQ.

Based on this value band, comparing the investment returns of network service providers and content service providers, we find that most content service provider samples are located above this value band, with many stocks reaching new highs after the network bubble. Based on this comparison, we can conclude that overall, investment returns in content service providers may be greater than those in network service providers; among content service providers, investment returns in e-commerce and search service companies may be greater than those in news media.

The above historical data and analysis results align with Altucher' s conclusion that the investment value of basic Internet service providers—network access providers and news media providers—has greatly diminished; they also align with Wilson' s conclusion that the investment value of e-commerce and search

services is likely to reach new highs.

We believe both Altucher' s and Wilson' s views are representative yet incomplete. However, their debate undoubtedly raises a series of thought-provoking questions for network economy and technology development: How should we view the Internet economic system? What is the interest distribution relationship in the Internet economic system? What is the economic explanation for this situation? How should we consider the direction of network technology development from an economic perspective?

3. Explanation and Development of Internet Contractual Characteristics

As shown in Figure 1, while information travels among multiple entities, it also associates them together, forming relational contracts similar to those discussed in institutional economics regarding relative property rights among multiple entities [1]. Below, we focus on the contractual relationships among various roles in the Internet to explore responsibility and interest distribution. Simultaneously, based on the interdependent demand curve [14], we provide an economic explanation for the data in Section 2 and visually illustrate the explanation through price torque. Finally, we discuss the possibility of enriching existing contractual relationships and transaction content, as well as promoting network economic development, by adding end-network openness to users as a new production factor to the Internet economic system.

3.1 Explanation of Internet Architecture Contracts

Physical networks are specific assets [8]. In telephone networks, this specificity forms industry barriers and monopolies. When bearer and service are separated, the specificity of physical networks remains unchanged; however, the equipment users use to exchange information through the network has more general-purpose characteristics. From the perspective of specific asset contract responsibilities: in data transmission, when users and content service providers use physical networks with specific asset characteristics, the contracts between network service providers and users/content service providers have rental contract characteristics [1]; in information services, when users and content service providers use physical networks, the contracts between network service providers and users/content service providers have sales contract characteristics [1].

According to institutional economics analysis of contract responsibilities, post-contract opportunistic behavior exists after users, content service providers, and network service providers sign contracts. The post-contract opportunistic behavior caused by sales contracts in information services—where data service content is not controlled by network service providers—causes network service providers to bear transmission costs in the development of high value-added information services. Under rental contracts, post-contract opportunistic behavior significantly increases user migration costs, giving network service providers more

initiative; however, typical post-contract user opportunistic behavior includes arbitrarily connecting multiple network devices or using bandwidth-intensive applications such as peer-to-peer (P2P) downloads.

On the other hand, competition among network service providers drives bandwidth rental prices toward cost levels. The information service between users and content service providers also has sales contract characteristics. Information redistribution is a post-contract opportunistic behavior in this type of contract. Meanwhile, to attract users, content service providers often adopt free services that consume high bandwidth, meaning they spend more on bandwidth rental fees. However, the free nature of the services makes it impossible for content service providers to pay high fees to network service providers.

The above discussion demonstrates that in the network economic system, content service providers and network service providers are two relatively independent variables. Below, we conduct an in-depth analysis of the above issues through supply-demand relationships. The greatest characteristic of the network industry is network externality: when the value of a product to users increases as the number of users adopting the same or compatible products increases, network externality emerges [5]. Network externality is also the essence of Metcalfe's Law [3]. The demand curve for the network industry economy differs from other industries. In 1974, Rohlfs from Bell Labs [4] proposed a demand curve for products with network externality characteristics—interdependent demand—and analyzed the relationship between price and number of users in telephone services. This curve is a downward-opening U-shaped curve. Becker [13] and others studied the restaurant industry with similar network externality characteristics, exploring why many people prefer to queue for expensive restaurants. From Alexa's website visit statistics, although large websites have more advertisements, they still attract more visitors. The "eyeballs" considered when websites sell advertising space have many similarities with restaurant seating supply and pricing, i.e., pricing based on expected visits. Synthesizing the above research, we compare the service pricing of network service providers and content service providers from the supply quantity perspective, as shown in Figure 4 [FIGURE:4]. Due to the large absolute differences in service prices and user numbers between network service providers and content service providers, for analysis convenience, we extract the relative positional characteristics of their respective supply quantities and vertices, and normalize prices and demand.

Figure 4 shows that the service provision models of network service providers and content service providers are quite different. Network service providers need to provide access services covering more than 50% of the population before scale effect advantages become apparent; content service providers do not need to cover 50% of the population. According to Rohlfs' research, once demand exceeds point A—the vertex of the demand curve—service prices will enter a downward channel. According to Becker's research, on the basis of improving information service content quality, maintaining appropriate supply scarcity will stimulate demand, thereby maintaining service prices at a relatively high

level, i.e., pricing based on expectations. Thus, although the information service supply quantity of websites is at point C, their service prices, such as advertising push fees, can be priced between C and A based on expectations. The area between C and A is their profit zone. Based on the relative proportional relationship shown in Figure 4, Figure 5 [FIGURE:5] further visually illustrates profit distribution issues through the investment return leverage system of network service providers and content service providers. When only considering network service providers providing more access, access service prices have further downward potential, leading to decreased investment returns for network service providers (lever arm shortening); simultaneously, this expands the absolute gap between C and A for content service providers in the opposite direction—increasing investment returns for content service providers (lever arm extension). When simultaneously considering content service provider factors, as more homogeneous service providers emerge, point C moves closer to point A. Although unit prices increase, for example by providing more attractive advertisements, content service providers' profit margins are compressed.

Under such fierce competition, price wars among large websites could break out at any time, leading to decreased industry-wide profits. Under the current network architecture, although opportunistic behavior benefits content service providers, their investment returns and expected visitor volumes are determined by the number of access users. Therefore, they urgently need more users to access the network. Overall, increasing user access numbers tilts the leverage system toward the ICP side while the system's center of gravity contracts toward the fulcrum. This indicates insufficient momentum in the network economic system, potentially leading to weakness. Therefore, while further expanding user scale, we must systematically study the factors in network architecture that constrain network economic development.

3.2 Development of Internet Architecture Contracts

Thus, we believe: (1) If content service providers can share part of their service revenue with network service providers to compensate for network service providers' losses in user development, network service providers will have greater motivation to develop larger user groups. (2) For network service providers, continuing to expand user scale cannot break free from the situation where service prices are locked in a downward channel. Therefore, an emerging market is needed to reprice network service providers' specific assets, and content service providers' compensation behavior toward network service providers also needs a market for allocation. (3) The Internet of Things will be the carrier of this emerging information service market. In the short term, a market targeting interconnection of things will provide network service providers and content service providers with a new opportunity for expectation-based pricing. In the long term, in the Internet of Things, network service providers need to strengthen their role as information service channels, thereby obtaining stable compensation for developing larger user groups through the bilateral lock-in

characteristics of channel service providers [4].

To achieve these goals, we need to introduce new factors of production into the Internet economy to change the interest distribution pattern limited by the contractual relationships shown in Figure 1. As shown in Figure 6 FIGURE:6, technology that provides end-network openness services to information consumers is a new technology clearly distinct from terminal equipment. From a contractual structure perspective, this new technology is a new production factor. It grants information consumers self-governing rights over end networks. This also adds new transaction content to the current network architecture: information service providers and data transmission providers offering end-network services to information consumers. This new service expands the original network economic system' s contractual structure, making transaction relationships more complex but also meaning new economic growth.

Transaction relationships (contracts) need to be matched with governance structures to promote economic development. Oliver Williamson argues that applying simple governance structures to complex transaction relationships will be inadequate [9]. According to Williamson' s theory, we believe bilateral governance is more suitable for situations where subjects cannot be unified under Internet architecture. Bilateral governance is equally important for users, network service providers, and content service providers because this governance structure allows for outsourced component behavior. Ordinary users have the right to deploy various outsourced information equipment and outsourced information services in the networks they control according to their different needs. This ensures the demand foundation for emerging markets exists.

As shown in Figure 6(b), based on the price torque model of network service providers and content service providers, we believe that opening end networks can balance the profit distribution relationship between network service providers and content service providers, and can become a stabilizer for maintaining sustainable network economic development. First, this stabilizer can stabilize network service provider prices, shifting network service providers from expanding ordinary user quantity to expanding end-network quantity. User quantity increase is handled by end-network operators. Second, the stabilizer' s emergence positions network service providers between content service providers and end networks, highlighting their channel role.

In fact, to solve problems such as data transmission optimization in P2P applications and widespread deployment of P2P operator services, network service providers and content service providers have already begun close cooperation. The US P4P (Proactive network Provider Participation for P2P) standard and the "Carrier-Aware P2P Traffic Optimization Technical Framework (Draft for Approval)" issued by China' s communications industry standardization organization are the most representative achievements.

4. Research on High-Autonomy Network Architecture and Service Model

It is difficult to demarcate clear sovereignty boundaries for opposing subjects within the current unified network address space. How to provide an end-open network environment for implementing bilateral governance under existing network technology has become a key issue in network architecture research. Below, this paper mainly discusses the operability of this governance structure in the current Internet, specifically including: the foundation of high-autonomy network architecture, feasibility practice, and service delivery models.

4.1 Foundation of High-Autonomy Network Architecture

A network technology architecture that facilitates collaboration at the information exchange service level while maintaining relative independence of network owners will be more conducive to all network system participants achieving optimal decision-making arrangements, thereby reducing transaction costs [6]. Comparing various technologies, address translation technology provides the most likely foundation for establishing such a network architecture with high local autonomy characteristics at the economic and management levels while facilitating application collaboration.

First, using address translation devices allows physical network owners to have more autonomy in selecting information services and information equipment. A class of identifiers called private addresses exists in the Internet; users can use these addresses to build internal networks. Internal network hosts can actively access external network hosts through address translation devices; in the reverse direction, address translation devices automatically block active access from external network hosts. This technology was rejected by network standardization organizations for nearly 20 years [16] because it severed unconditional bidirectional data transmission. However, this characteristic provides a clear boundary for the address space of network architecture, offering greater space for decision-making freedom. This boundary is the basic guarantee for establishing emerging information service and information equipment outsourcing markets. Based on such boundaries, like water and electricity users who can add faucets and electrical interfaces as needed, network users can also add, manage, and control information equipment in end networks according to their habits and preferences. Simultaneously, this boundary provides a basic network environment for developing secure, trustworthy, and virtualized network services that can cover the entire network.

Second, a network architecture based on address translation technology has laid a material foundation for widespread use worldwide. After nearly 20 years of development, address translation technology has achieved considerable scale in the Internet. The SOHO ROUTER is a typical device using address translation technology. Taiwan's production from 2002 to 2006 is shown in Figure 7 [FIGURE:7]. In 2006, actual production accounted for 80% of the world's total,

approximately 33.486 million units, with output value reaching \$1.091 billion. Seventy percent of its wired and wireless network products were sold to North America, Europe, mainland China, and other markets. Based on this production scale, since 2002-2008, no fewer than 100 million address translation-capable devices have been deployed in the Internet. Behind these address translation devices, hundreds of millions of network users or online households are also hidden.

Furthermore, the Internet Engineering Task Force (IETF) has explicitly stated that IPv6 networks will connect to IPv4 networks through address translation technology [12]. At least at the current stage, IETF has abandoned the view of developing networks based on a single address type, essentially recognizing the fact that networks need to be built on the basis of multiple address types. This also indicates that under current economic conditions, the sustainable development of the network economy requires us to explore new approaches in a network environment where multiple address types coexist.

4.2 Feasibility Practice of High-Autonomy Network Architecture

Academia and industry have conducted years of research on network architecture based on address translation devices. We believe that architecture selection needs to balance compatibility and development—compatibility with existing network protocols and applications will save network development costs and increase development speed in economic, technical, and future development aspects; the openness caused by interconnection of things brings new problems in management, control, security, and configuration, which are the themes of future development.

Focusing on the issue of opening end networks, we propose a network architecture that can be built on multi-layer address translation technology devices—the IPVN (IP-based Virtual Network) [2,3] system. This architecture starts from the session layer to solve the problem of controlling interconnection of end-network applications. The system combines signaling control, channel establishment, and data transmission, extending the vertical stacking mode [7] between protocols to a horizontal aggregation mode in the original network protocol layering model, expanding the usage of network layering model principles while solving practical problems (Figure 8 [FIGURE:8]). The specific implementation steps are: first, as shown in Figure 8(a), under the control of session layer protocol control (SIP) [15], establish data transmission tunnels between ends; then, as shown in Figure 8(b), when applications execute, the TCP/IP protocol stack automatically establishes correspondence between the application and the tunnel, and the application sends and receives data through this tunnel.

This architecture establishes a solid network security foundation for network applications. First, this architecture uses user registration as the addressing foundation. This addressing system provides a manageable and controllable network real-name environment, strengthening network trustworthiness and fa-

ilitating the development of secure, convenient business delivery information systems that serve human life. Second, address translation devices add security domain properties to user-open end networks from the Internet address principle level, forming atomic security domains.

4.3 Virtualized Service Delivery Model

Referencing the hierarchical model of living environments [10] (Figure 9 [FIGURE:9]), we propose a virtualized service delivery model for “digital human living environments” based on IPVN, as shown in Figure 10 [FIGURE:10]. This model takes the home network as the core space—the private space—and defines community networks, community service systems, and digital cities as secondary semi-open spaces, primary semi-open spaces, and open spaces, respectively. These spaces center on the private space and combine according to specific environments.

Based on the IPVN structure, according to the definition of each space’s specific business functions and business access relationships, we use IP technology to connect address translation devices in nested or parallel configurations, forming a network configured according to autonomy requirements. After each space is configured, the IPVN system controls the opening of information exchange channels between atomic security domains based on the access relationships defined by each security domain. Applications within each autonomous space are determined by that space’s owner. Based on such a control relationship, as the core space of digital life—the private space—can access networked devices in open or semi-open spaces while itself not being accessed by unauthorized space networked devices.

5. Conclusion

Network architecture research is directly related to economic development. This paper uses the main theoretical analytical tools of institutional economics—transaction cost economics and contract economics—to analyze the contracts derived from network architecture. This analytical method helps us understand the microeconomic significance of network architectures with macro-level characteristics, making network architecture research more practically valuable.

Through analysis of the contractual characteristics of Internet architecture, this paper discusses why the investment value of basic Internet service providers—network access providers and news media providers—has greatly diminished. We propose a development model for promoting network economic development by opening end networks to users and increasing end-network autonomy. Simultaneously, we present a technical solution for implementing open end networks—IPVN—and propose a service delivery model serving human living needs based on this solution—digital human living environments.

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