Modeling the Adaptability of Network Protocol

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Abstract

The adaptability of network protocol(ANP), which means whether the protocol can be deployed to the network and used extensively after a period of evolution. Many protocols developed slowly or failed, although they meet the requirements of design technically. We propose a new approach which has two modules to evaluate the ANP, self-evolution model(SEM) before the protocols deployed to the network and user dynamic behavior evolution model(UDBEM) after the protocols applied to the real network. SEM determines whether the new network protocol can survive by simulating the evolution process of the protocols in the protocol stack. UDBEM counts the new user's share by simulating the transformation process of new protocol users' states in logical network. We propose the evaluation model on the basis of communication efficiency, then measure the ANP by calculating the communication efficiency of the new protocols evolves to the final states through the model. We also present some factors which affect the ANP and methods to improve the ANP by analyzing these factors. After theoretic model simulation analysis, we draw some conclusions. The protocols at the waist of the hourglass appear to have less survival, while the lower and higher layers tend to live longer and easier. Increasing the utility, the external utility of the protocol and the efficiency of the converters appropriately play important roles in improving the ANP. The network protocol adaptability evolution model we proposed can be applied to assess the ANP.

Key Words: Adaptability, Network Protocol, Communication Efficiency, Penetration

1 Introduction

The Internet community has specified a large number of protocols to date, although they were developed, these protocols have achieved varying degrees of success. Two major dimensions on which a protocol can be evaluated are scale and purpose. Purpose can be explained whether the protocol could meet the design goals, which belongs to technical areas. Scale relates to the protocols are deployed at last, whether the numbers of users expected. Lots of protocols were not deployed extensively. For example, IPv6 caused great concern since 1996, its deployment and usage is not optimistic at the moment compared to IPv4 [4]. Most research on IPv6 is focus on technical research, such as, IP address allocation, dual stack coexistence, new network protocol and so on, which make it dose not get enough attention about how to deploy and operate. That's why IPv6 develops so slowly although we make lots of progress [5]. The research and development about network protocols is not just a technical problem, but the benefits, deployment expense and switch costs which are important factors about whether the protocols can be accepted by users after applying to the network [7][8]. The degree of users' acceptance of the protocols called *adaptability* after they are applied to the network for a period. So not only the features and performance should be focused but the adaptability when we develop the protocol. Researching on the ANP helps developers focus on improving the performance and the degree of acceptance of the protocols. That makes different for lowering the costs and reducing the blindness of protocol development. The emerging of various theories and methods lay a foundation for the ANP research and makes the ANP a very popular at home and abroad. However, the research of ANP is never easy, because the developers did not take economic, environment factors into consideration even based on false assumptions. Besides, common agreement has not been reached about how to evaluate the ANP, that's the problem to be solved.

2 Problem Analysis

The methods focused on the ANP research has two categories, measuring the ANP directly and modeling analysis. Traditional studies suggest that there are five factors can affect the deployment of a new protocol, they are the advantage of new protocol, compatibility, complexity, workability and observability. They study the effects of economic factors, external network utility on the deployment of protocol from economic perspective by visiting equipment manufacturers, application providers, ISP and users then evaluate the adaptability of IPv6 [10]. Colitti.L et al evaluate the adaptability of IPv6 as a user. When users post HTTP requests, they can choose post the data to the sever by IPv4 or by dual-stack. They apply this method to Google then count and analyze the post data over past year, and the result shows a small-scale IPv6 deployment [11]. Zhus' opinion is that reasons affecting the ANP are complex, and it is impossible to draw a conclusion by simple simulation or performance measurement. They visited 19 experts and have a discussion about the problems of HIP protocol is not widely used and its deployment policy from June 2011, 16 to September 1, and finally analyze the reason why HIP protocol is not widely deployed. On the one hand, measuring the adaptability directly can analyze the ANP in some degree but the result is not convincing, on the other hand, the evaluation of the ANP based on measurement should be executed after the protocol applying to the network. While the evaluation always fall behind in development, so the evaluation cannot provide theoretical guidance at the beginning of develop the protocol [7].

To further characterize the evolution of the protocol in the network, scholars begin to use modeling method to analyze the ANP, the adaptability model can be divided into two major categories of static and dynamic. Hovav et al has established a model for describing protocol adopted by users and evaluated the impact of various factors on the deployment of the IPv6 protocol from environmental triggers and its features [12]. Gyarmati et al applied game theory to the research and study about transition and deployment of IPv6, they take the Internet ASs as interconnect and independent players and treat these ASs can choose their running network protocol. The study shows that if all the ASs running IPv6 that will be Nash Equilibrium, and if there are some ASs deployed IPv6 at the beginning in the Internet then the whole network will be deployed IPv6 faster and more feasible [13]. The author modeled the LOC/ID protocol, if the LOC/ID want to be deployed extensively, not only its own technical advantages but economic factors encountered during its deployment. The scale of LOC/ID depends on the reduced price and the efficiency of deployment, and the price of LOC/ID deployment must be less than BGP protocol [14]. They analyze the effects of the converters and other economic factors using differential equation. The authors assume that there are two different architectures, and the share of deployment is x_1 and x_2. Then they take the technoligy, the share of deployment and the price on different users' utility into consideration and build a dynamic economic model of technology deployment. They find than there is a balance during the deployment of two protocols even though they have different share at the beginning of deployment [15]. These studies examined how the user choose the two incompatible protocols. The articles focus on how the converter help the users who using incompatible protocols to interact. Studies indicates that the external network will lead more balance, and the converter make a great different on balancing the deployment [16] [17] [18]. Farrel extended the above model to a new architecture, this model evaluated the ANP from a practical aspect to the user's perspective rather than an ISP or a equipment supplier. The model assumes that there are N users, each user will choose a protocol A or B, so if the utility of B is greater than A, users of protocol A switch to protocol B. Then A, B protocol can achieve the purpose of coexistence through the converter. We can evaluate the ANP by analyzing the utility of one single user and all users. Zhu, etc propose the evaluation method for the application of the ANP based on its architecture, and construct the corresponding evaluation model [20]. Two mechanisms about multimedia data application are evaluated in this paper, the result shows that both theoretically advantageous protocols should be deployed under certain restrictions in order to play their advantage. Users and ISP should combine with own application requirements to choose the corresponding architecture and protocol to deploy.

Because the static model cannot describe the dynamic process of the acceptance of the protocol, the researchers establish a dynamic model of the ANP and Internet protocol for analysis. They analyze the coexistence of more than one network protocols and the dynamic of the ANP in single user and system. The authors note that when a plurality of balance exist, a change in the parameters of the deployment system will affect the balance significantly [21]. In order to demonstrate the problems during the deployment, Eardley propose a architecture and apply it to the multipath TCP and Congestion Exposure analysis [22]. In this paper they use non-cooperative game theory for finding the most suitable flow control protocol of each data flow. Each flow has a utility that depends on throughput and a disutility depends on the queue lengths encountered along the route taken. Flows will choose a combination of protocols that would maximize their utility, then the available bandwidth will be distributed to them in a fair game way [23]. They then consider the practicalities of these guidelines, with a specific focus on Quality of Service issues and highlight some technical areas that will require further research if Ambient Networks are to be designed in a "migration friendly" way [24]. Akhtar by building models reveal "lock-in" phenomenon depends mainly on the impact of network topology influence and potential users of the protocol, and analyzes the factors that influence differences on the same network at different network topologies selected by the user [25]. Joe-Wong develop a model for user adoption of a base wireless technology and a bundle of the base plus a supplementary technology [26]. This paper studies the effects of the maximum utility and the deployment coverage on the balance of a outcome. Akhshabi establish a abstract model EvoArch, which reflects the evolution of the OSI protocol stack. He says that there will be competition among the same layer protocols for providing the same services for upper protocols [27]. Li and Xu et al extends the model [13], and apply the extended model to analyze trends in the triple play of Internet, telecommunications and television networks [28]. Studies shows that no matter what is the original proportion of the three networks, they will eventually converge to one or two networks and the higher proportion of initial network has more advantage.

We propose a model of the ANP based on the existing analysis of adaptability, and simulate the evolution process. Then analyze the factors affect the ANP and raise new methoda which can improve the adaptability by researching the change of share from the beginning to the final state during the evolution of a new protocol. Users will establish a connection depend on the status. Then we will evaluate the ANP by calculating the communication efficiency.

3 Model Description

As is shown in Figure 1, the protocol evolution can divide into two stages. (1) The Self-evaluation Stage, propose a evolution model in protocol stack according to the protocol location, competitiveness and vitality of the protocol before being deployed to the network, then we can get the initial penetration of a new protocol after being deployed in real networks. (2) The Internal Evolution Stage, after the deployment of the new protocol to the network, we must calculate the economic utility of each node firstly, then we can get the final penetration of the new protocol according to the state transition policy based on user protocol. When the internal evolution comes to the final state, the nodes can establish network topology according to the states and the protocol communication strategies of them, then evaluate the ANP by calculating the communication efficiency.

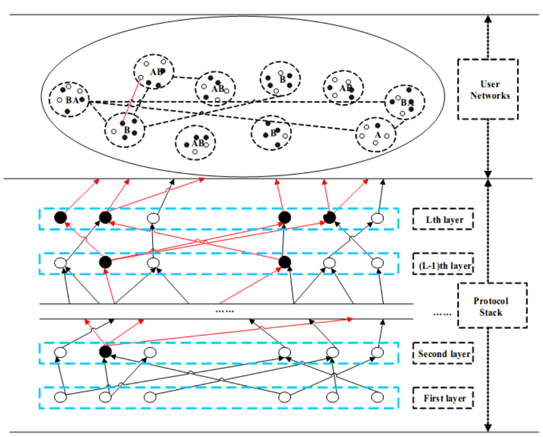

Figure 1 Dynamic Evolution Model of Network Protocols

3.1 Self-evolution Model

The Internet protocol stack has a layered architecture that resembles an hourglass. Akhshabi also propose a model based on the hourglass-shaped Internet protocol stack to explain how the model relates to protocol stacks and evolving network architectures.The evolution of layered protocol stacks leads to an Hourglass-Shaped Architecture. That help us understand the self-evolution of the protocols.

3.2 User Dynamic Behavior Evolution Model(UDBEM)

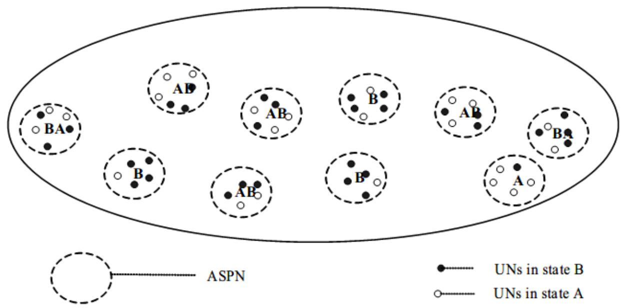

Figure 2 Network Topology

As is shown in Figure 4, there are two kinds of nodes, User Nodes(UN) and Application Service Provide Nodes(ASPN). The UN is someone who choose the service provided by a new protocol. The UNs are different according the protocols they chose, for example, the network layer is a network composed of routers and ISP [42]. The ASPNs provide service for UNs, for example ISP can provide Internet service for users and they can get profits from users. A ASPN can provide service for dozens of UNs. The UNs can establish a physical topology, while the relationship between UNs and ASPNs form a logical network. The UNs have two states A and B, where A represents the user still use the current protocol, B states indicates that the UN choose another new protocol which can provide the same service compared with the old one. The more B state users, the better adaptability of the new protocol has. The ASPNs have four states, A, B, BA and AB, where states A represents that the ASPN can only provide the service of protocol A, service B cannot be provided, vice versa, while states AB indicates the ASPN can provide the service of protocol A, and compatible conversion interface for protocol A users of protocol B, vice versa.

The transition strategy between ASPN and UN is as follows: The transition strategy between ASPN and UN depends on the utility of them, so the utility U_A of a single UN in state A is:

$$U_A = \alpha_A + \beta N x_A + \beta N(1 - q_A)x_B$$

where α in (3.2) represents the utility provided by protocol A, Nx_Aindicates the amount of A users who communicate to this protocol A user and $\beta N x_A$ represents the whole utility provided by Nx_Ausers who communicate to each other. $\beta$is the influence coefficient controlled by network. And Nx_Brepresents the numbers of protocol B user who communicate to this A user and the $\beta N(1 - q_A)$ represents the utility provided by $N_B$protocol B users who choose the BA converter.The $(1 - q_A)$indicate the utility comes from A state users interact to the A state users. Similarly understood, the utility $U_B$of a single UN in state B is (3.2):

$$U_B = \alpha_B + \beta N x_B + \beta N(1 - q_B)x_A$$

The utility $U_{ASPN(A)}$ of the ASPN in state A is (3.2):

$$U_{ASPN(A)} = \alpha_A + N_1 x_A + N_2 x_B + N_3 x_B(1 - q_A)$$

where $N_1 x_A$, $N_2 x_B$ represent the number of the users in state A and state B separately, $N_3 x_B(1 - q_A)$ represents utility of the A state user who communicate to the B state users by BA converters. Similarly understood, the utility $U_{ASPN(B)}$of ASPN in state B is (3.2):

$$U_{ASPNB} = \alpha_B + N_1 x_B + N_2 x_A + N_3 x_A(1 - q_A)$$

The utility $U_{ASPN(AB)}$of the ASPN in state AB:

$$U_{ASPNAB} = \alpha_A + N_1 x_A + N_2 x_B + \sum_{i=0}^{Nx_B} (1 - q_B) N_i x_B$$

where $\sum_{i=0}^{Nx_A}(1 - q_A)N_i x_B$ is the utility that $N_i x_A$ communicate to the B state users within ASPN who provided the AB converter, N_i represents the number of B state users who communicate to the ith node. Similarly understood, the utility $U_{ASPN(BA)}$ of the ASPN in state BA:

$$U_{ASPN(BA)} = \alpha_B + N_1 x_B + N_2 x_A + \sum_{i=0}^{Nx_B} (1 - q_B) N_i x_A$$

Whether the state will change at a time depending on whether the node can obtain more utility after changing the state. For the UN, if the switch the protocol from A to B, the following conditions must be met:

$$U_A + S \leq U_B$$

that is the sum of the utility and the cost for the user from state A to state B less then the utility of state B. For ASPNs, there are four states of transformation, state A to state AB, state AB to state B, state A to B and state B to state BA, but the conditions must be met:

$$\begin{aligned} U_{ASPN(A)} + S &\leq U_{ASPN(AB)} \\ U_{ASPN(AB)} + S &\leq U_{ASPN(B)} \\ U_{ASPN(A)} + S &\leq U_{ASPN(B)} \\ U_{ASPN(B)} + S &\leq U_{ASPN(BA)} \end{aligned} \tag{1}$$

The following will introduce the model algorithm in detail.

Firstly, check the initial state of each user of the network according to the new protocol, then set the numbers of ASPN areas and state of ASPNs. The UDBEM is a discrete-time evolution model, There are two following steps for every evolution process:

1. Calculate all the UNs and ASPNs' utility.
2. Revise the states for each node according to the transmission policy.

Calculate the utility and revise the states according to the policy after the network reaches a steady state.

3.3 The ANP Model of Evaluation Based on the Network Connection States

3.3.1 Build the Communication Topology

Every node in the network will reaches to the final state within the dynamic evolution model, as is shown in Figure 5, the number of B state nodes in the final state. The number of B state users is the appearance of the ANP, while the reason that causes the protocol selecting is the communication efficiency provided by the protocols. So the relationship between the ANP and the final stage of evolution is that the UNs and ASPNs will establish a topology and communicate based on the transmission policy and the state pf the users in the final evolution stage.

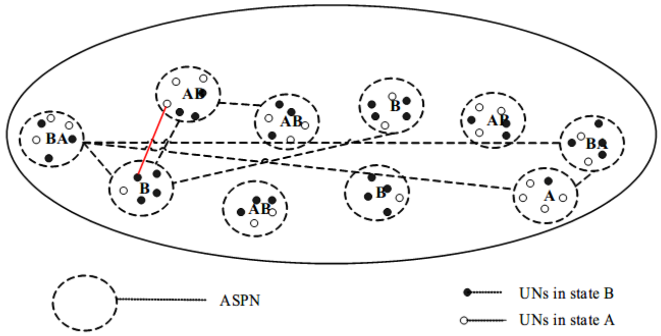

Figure 3 The communication network topology

The connection among the ASPNs is already known to the UNs, and the connection among UNs in different areas charged by different ASPNs determined by the connection of ASPNs. The connection among the ASPNs is shown Figure 5.1, and the "$\surd$" represents the connection can be established between the converters, the "$\times$" not.

ASPN Nodes \ ASPN Nodes	A	AB	B	BA
A	√	×	×	√
AB	×	√	√	×
B	×	√	√	×
BA	√	×	×	√

Table 5.1 connection relationship of ASPNs

AS we can see from the chart, the ASPNs in different states can only establish connection between the UNs within the specific ASPN. We obtain the connection relationship as shown in Table 5.2 according to the connectivity rules.

3.3.2 Calculate the efficiency of communication

Assume a communication network topology is a graph G which has M edges, N points, so the communication efficiency is calculated as follows:

1. Firstly, according to the position and the state of the nodes, we can establish a cost function $F(i,j) = \eta(\eta \geq 1)$ between two nodes, so the communication efficiency of each edge $e_{i,j}$ is $1/\eta$.

2. Then, the communication efficiency between i,j is $\varepsilon_{i,j}$, which can be expressed as the sum of every edge communication efficiency
$$\varepsilon_{i,j} = \sum \frac{1}{F(i,k)} + \frac{1}{F(k,r)} + \cdots + \frac{1}{F(s,j)}$$
where k, $r ... s$ are the shortest path sequences which pass the i,j.

3. The communication efficiency of G is $E(G)$
$$E(G) = \sum_{i \neq j \notin G} \varepsilon_{ij}/[N(N-1)]$$
as you can see, the more close to 1 of $E(G)$, the closer the value of $E(G)$ is to 1, the higher the communication efficiency. We can get the indicators of the ANP by calculated the $E(G)$, then evaluate the ANP.

Table 1: The Basic Paprameters

L	n_0	μ	N_{max}	c
10	10	5%	1000	0.7

Table 2: The Basic Paprameters

L	α_A	α_B	q_A	q_B	β	S	N	M
10	1000	1900	0.1	0.1	0.001	1500	1000000	1000

4 Model Analysis

4.1 Self-evolution

As is shown in Figure 3.8, 3.9 and 3.10, the new protocol layer in the protocol stack 10, 50, 100, its initial proportion of the new protocol is the first after decreasing increasing trend. So the initial proportion is minimum of intermediate layer, while from the middle to upper or lower layer showing an increasing trend initial proportion. The protocols in the middle layer is hard to survive and has a small proportion if the protocols are deployed in the network. The reason for this phenomenon is the protocol stack presented hourglass, the lower and higher layers tend to have more survival and the waist of the hourglass appear has less survival.

4.2 Evolution Model Based on Dynamic Section of User Behavior

The basic parameters of the experiment described as shown in Table 4.1,

4.2.1 The Influence of the Protocol Utility to Adaptability

As is shown in Figure 4.1, the ANP will increase if we increase the utility of protocol B, we can get the penetration changes with time of protocol B with the different α_B/α_A. The higher utility of a new protocol, the less time needed to get the whole penetration. You can see the penetration varying depending on the different α_B/α_A in Figure 4.4. When the new protocol provides for its own utility 1.8 times the current, the case of penetration of the new protocol dose not change. The reason is that the current utility is greater than the new protocol under the current network state. When the new protocol provides for its own utility is 1.8 times of the current and the simulation proceeds to the 50th, the new protocol get 100 percent penetration, which entirely depends on the parameters of the experiments selected. When the new protocol provides for its own utility is 4 times of the current and the simulation proceeds to the 10th, the new protocol get 100 percent penetration.

4.2.2 The Influence of the External Network Utility to the Adaptability

As is shown in Figure 4.5, the ANP will increase if we increase the network utility. When the utility of the external network value is too large, it will hinder the new protocol to enhance the proportion. The picture shows the changes in the penetration of the new protocol under different utilitise of the external network effect β. The value of α_B/α_A is fixed at 1.9 to ensure that the new protocol is acceptable to the user. When there is no external network utility, that is $\beta = 0$, the penetration of the new protocol stops at 67.4%. As the new protocol of its own utility, so the state A users are willing to switch to state B to obtain higher returns, Some A-State users have already achieved high utility in the existing network environment, and the transition to state B does not get higher utility, so the user chooses to keep the existing state, which is why the new protocol's penetration rate will stop. An increase in the external utility from the state B user increases the number of users switching to the B state, which encourages the user to switch to the state

B. When β is 0.001, the new protocol can be completely infiltrated. If the external network utility is too large, will inhibit the penetration of the new protocol.For example, when β is 0.010, since the state A user occupies a considerable proportion of the initial state and get enough income, so the state users do not need to convert the state to obtain additional utility, so the new protocol Of the penetration does not change. If we set the new protocol can reverse the conversion, B protocol users will choose to switch to B state to get more utility. At this point the utility of excessive external network will not only promote the penetration of the new protocols but will inhibit the adaptability of them.

Figure 4.1

4.2.3 The Influence of the Converter to the Adaptability

The result of simulation indicates that, the increasing utility of AB converter []. As expected, the efficient AB converter can reduce the cost of state transition A to B. However, the efficient converter AB can bring utility of B to A from the perspective of individual, so there is not any incentive for A with or without converter BA.

From the other hand, after the users changing the state A to B encouraged by BA converter, they can get the utility from other state A users and B state users changed from state A. As is shown in the simulation results, at most cases, the ANP will improve if the utility of BA converter increase. The Figure 4.6 indicates that, when the efficiency of the BA converter is 92.5%, it will take more time for the new protocol to get to the full penetration than the efficiency of the converter is 98%. Besides, we draw the conclusion that penetration can be blocked when we improve the efficiency of the converter in some case. When BA converter efficiency from 92.5% to 94.5%, the penetration of the new protocol will stop at 95%. The reason is when the simulation is stopped, the A state users will get more utility than cost for changing to state B. For the remaining A state users, since more and more users change to state B, they will get more utility from B state users. Efficient BA converter will increase the utility generated by state B users, so more users will be encouraged to state B. Since the BA converter is bidirectional, efficient BA converter will increase the utility for remaining A state users and preventing them from converting to state B.The result suggests that the ANP will improve if we increase the efficiency of the converter BA and keep a low level. Furthermore, the efficiency of the BA converter must be maintained at a certain range in order to promote the new protocol fully penetrate.

Figure 4.6

4.3 Evaluation Model of the ANP Based on Network Connection Status

There 10 million nodes in the network topology, we take the cost of the connection between two nodes is $varepsilon = 4$, so the communication efficiency $1/\varepsilon$ is 0.25 of any edge $e_{i,j}$.

4.3.1 The Influence on Communication Efficiency of the Protocol Utility

Figure 5.2 shows the changes of the communication efficiency at different α_B/α_A,when $\beta = 0.001$. As is shown in the picture, the communication efficiency of the network grows faster and has significantly improved with the development of the utility of the new protocols. It can be concluded that improving the efficiency of the new protocols will help to improve the communication efficiency of the network, that is, improving the efficiency of the new protocols will help to improve the ANP.

Figure 5.2

4.3.2 The Influence on Communication Efficiency of the External Network Utility

Figure 5.3 shows the changes of the communication efficiency at different β and $\alpha_B/\alpha_A = 1.5$. As is shown in the picture, the communication efficiency has improved with the improvement of the external utility of the network. But when the utility reaches to a certain value, the communication efficiency of the network significantly reduced. It can be conclude that improving the external network utility will help to improve the communication efficiency, but the efficiency will decrease when the external network utility is to high. So improving the external network utility appropriately helps to improve the ANP of new protocols.

Figure 5.3

4.3.3 The Influence on Communication Efficiency of Converters

Figure 5.4 Figure 5.4 shows the changes of the communication efficiency while $\beta = 0.001$, $\alpha_B/\alpha_A = 1.5$, at different conversion efficiency of the BA converter. As is shown in the picture using converter can improve the communication efficiency, but the communication efficiency of the network will decrease when the utility of BA converter grows to a certain range. While if the efficiency if the converter is high enough, it dose greatly improve the communication efficiency of the network. It can be concluded that improving the efficiency of the converters appropriately helps to improve the ANP.

5 Simulation Analysis

5.1 Comparative Experiments A and B

The basic experiment parameters are set as follows,

参数	取值	参数	取值
协议出生率	5%	用户节点 U 数量	10000000
竞争阈值 c	0.7	USP 节点数量	100
IPv4 协议的质量 $q(IPv4)$	4	IPv6 协议的质量 $q(IPv6)$	2
IPv4 协议的自身收益 α_{IPv4}	1000	IPv6 协议的自身收益 α_{IPv6}	2000
IPv4-IPv6 转换器的效益(1-q_{IPv6})	80.5%	IPv6-IPv4 转换器的效益(1-q_{IPv4})	92.5%
外部网络效益值 β	0.001	协议转换代价 S	1500

Table 6.1 Basic Parameters

The Figure 6.2 represents the average probability of IPv4 and IPv6 exist in the stack after modeling the self-evolution many times. As we can see from the result, the more the number of experiments, the probability of the final IPv6 protocol decreases in the protocol stack. It can be seen in the evolution of the protocol stack that the IPv4 protocol cannot be fully replaced by the IPv6. The reason is that, the greatest contribution of IPv6 is to provide more addresses not additional new services compared to IPv4. The upper layer service of IPv4 and IPv6 is almost no difference, so there is competition between IPv4 and IPv6 protocol. IPv6 protocol is not widely deployed, so its quality indicators is lower than IPv4, that's why IPv4 is more competitive than IPv6. Much work need to be done if want replace the IPv4 by IPv6 protocol. On the one hand, IPv6 should provide some services that cannot provided by IPv4, which means that IP has more service nodes in the upper layer than IPv4. On the other hand, the competition should be avoided between IPv4 and IPv6, particularly in the deployment of the IPv4 is much higher than IPv6 protocol. Under these circumstances, we can make IPv6 as a "Second layer protocol" to provide services for the upper layer not a competitive protocol to IPv4.

Table 6.3, 6.4

As is shown in Figure 6.3, when the utility of external network $\beta = 0.001$, the efficiency of IPv6-IPv4 converter is 92.4% and the IPv4 and IPv6 protocol utility ratio $\alpha_B/alpha_A$ is 2, the IPv6 can be accepted and completely replace IPv4 to achieve the full penetration, although it develops slowly. The reason is that the government promote the deployment of IPv6 vigorously which can make up for the economic losses during the deployment. If the adaptability of the IPv6 wanted to be improved, we can do it in three ways: improve the utility of IPv6 protocol, to make it more competitive compared to IPv4; Improve the external utility of the protocol, the government can make up for the economic losses for deploying the IPv6 protocol; Improve the efficiency of IPv6-IPv4 converter, let the IPv4 users are willing to use the IPv6 protocol.

5.2 The comparative Experiments of UDP and DCCP

The basic experiment parameters are set as follows,

参数	取值	参数	取值
协议出生率	5%	用户节点 U 数量	10000000
竞争阈值 c	0.7	USP 节点数量	100
UDP 协议的质量 $q(UDP)$	4	DCCP 协议的质量 $q(DCCP)$	4
UDP 协议的自身收益 α_{UDP}	1000	DCCP 协议的自身收益 α_{DCCP}	1800
UDP-DCCP 转换器的效益(1- q_{DCCP})	92.5%	DCCP-UDP 转换器的效益(1- q_{UDP})	92.5%
外部网络效益值 β	0.001	协议转换代价 S	2000

Table 6.2 Basic Parameters

The Figure 6.4 represents the average probability of UDP and DCCP exist in the stack after modeling the self-evolution many times. As we can see from the result, the more the number of experiments, the probability of the final DCCP protocol decreases in the protocol stack. It can be seen in the evolution of the protocol stack that the UDP protocol cannot be fully replaced by the DCCP.

Figure 6.5 6.6

We build 7860000 UDP users and 2140000 DCCP users in the network which has 10000000 nodes, utilizing the UDP users share and DCCP users share from the protocol self-evolution model and according to the evolution model based on dynamic selection of user behavior. All the users reached to steady state after a period of evolution. As is shown in Figure 6.5,when the utility of external network $\beta = 0.001$, the efficiency of DCCP-UDP converter is 92.4% and the IPv4 and IPv6 protocol utility ratio α_B/α_A is 1.8, the DCCP can be accepted and completely replace UDP to achieve the full penetration, although it develops slowly. Besides, when the DCCP share reaches around 39%, it will not change any more. If the adaptability of the DCCP wanted to be improved, we can do it in three ways: improve the utility of DCCP protocol, to make it more competitive compared to UDP; Improve the external utility of the protocol, the government can make up for the economic losses for deploying the DCCP protocol; Improve the efficiency of DCCP-UDP converter, let the UDP users are willing to use the DCCP protocol.

6 Conclusion

We can draw some conclusions from the protocol self-evolution simulation. First, the protocols at the waist of the hourglass appear to have less survival, while the lower and higher layers tend to live longer and easier. Second, if we improve the utility of the protocol, the external utility of the protocol and the efficiency of the converters appropriately can play important roles in improving the ANP. Third, the higher efficiency of the communication, the better ANP by establishing network topology based on the interact policy of the users and nodes. Forth and last, the network protocol adaptability evolution model we proposed can be applied to assess the ANP, according to the comparative experiments of IPv4, IPv6 and UDP and DCCP. The network protocol adaptability evolution model guiding significance for the development and deployment of the network protocols.

Our model can simulate the dynamic evolution of the new protocols, furthermore, to measure the adaptability through the communication efficiency of the network topology established. In addition to this, we also proposed methods to improve the ANP. But we still have some shortcomings about the model need to be further refined and improved. In the future, we can establish a protocol dynamic evolution model and check by simulating, then evaluate the ANP by deploying to the real networks. We can also focuse on other factors which affect on the ANP, increase the availability of the model.