DOLPHIN: THE MEASUREMENT SYSTEM FOR THE NEXT GENERATION INTERNET

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ABSTRACT
With the growth of IPv6 research and application, the next generation Internet was widely developed around the world. The paper presents an IPv6 Internet measurement system named Dolphin, which performs the network measurement work of IPv6 backbone. The paper introduces the system realization and architecture of Dolphin system, and then analysis the data collection of next generation Internet.

KEY WORDS
IPv6 Internet, Network Management, Dolphin System, Internet Tools, Topology Discovery, Tunnel

1. Introduction

With the high speed development of Internet, the current Internet is limited by the limited IPv4 address space which is not free for the increasing requirement. So the next generation network based on the IPv6 protocol was developed to replace the current Internet based on IPv4 protocol. The IPv6 protocol has 128 bit sized IP address space which can supply 3.4* 10^38 IPv6 addresses in theory and IPv4 protocol only has 32 bit sized IP address space. In additional, IPv6 protocol extended the route protocol, and IPv6 Internet will coexist with current IPv4 Internet during the transition stage. Some new techniques such as tunnel, double protocol stack nodes and address transformation have been developed to keep connection between IPv6 Internet and IPv6 Internet under developing.

The next generation Internet has been built for research and business testbed for a long time. The famous 6bone testbed has been connected with a large number of IPv6 network include business or research IPv6 network distributed in the world. The 6bone is an IPv6 testbed that is an outgrowth of the IETF IPng project that created the IPv6 protocols intended to eventually replace the current Internet network layer protocols known as IPv4 [1]. According to the register data from 6bone in 2004, there're more than eight hundred IPv6 testbed has joined with 6bone. And in China, a largest IPv6 network at the present time, which called China Next Generation Internet (CNGI), is being understructure. It's the main infrastructure of future Internet in china, and also be connected with current IPv6 Internet.

The National lab of software development environment (NLSDE) of Beihang university [2] has start the research on IPv6 from 2003. Network measurement for the next generation Internet is the main research area of NLSDE. The lab focus its research on network topology discover and performance monitoring for the IPv6 backbone, and some system or tools were developed to measure and monitor the status of IPv6 Internet. Dolphin system was developed by NLSDE at 2004, which based on the research of IPv6 Internet measurement techniques. Its function includes the real-time network topology discover and performance measurement to the next generation Internet. It tries to gain the basic data of IPv6 Internet and help the application research on the next generation Internet.

2. Dolphin System

There're several research projects which do the same work as what Dolphin system does. CAIDA (the Cooperative Association for Internet Data Analysis) may be the most famous one of them, which provides tools and analyses promoting the engineering and maintenance of a robust, scalable global Internet infrastructure [4]. With the additional to its works on the IPv4 Internet, CAIDA began their measurement and analyses on the IPv6 Internet at 2003. The oldest data of IPv6 Internet was released at Aug 2003, and the second release of IPv6 Internet data was finished at March 16 2005.

There're many important difference between Dolphin system and CAIDA. Dolphin system releases its first IPv6 Internet topology map at March 1 2005, not like CAIDA, Dolphin system is a real-time measurement system which updates its data every day. So we can track the development and changes of IPv6 Internet according to Dolphin's continualness work. And, Dolphin system uses the technique of IPv6 over IPv4 tunnel to realize the distribution system structure, which is only created and

adopted by Dolphin system and have the advantage of scalable function. Dolphin uses its own probing algorithm which enables system to collect both topology and performance information of the IPv6 Internet, but CAIDA only collects the topology map. According to the current released data, the result data from Dolphin system is more complete than what CAIDA does.

Dolphin system includes some components as what figure 1 displays.

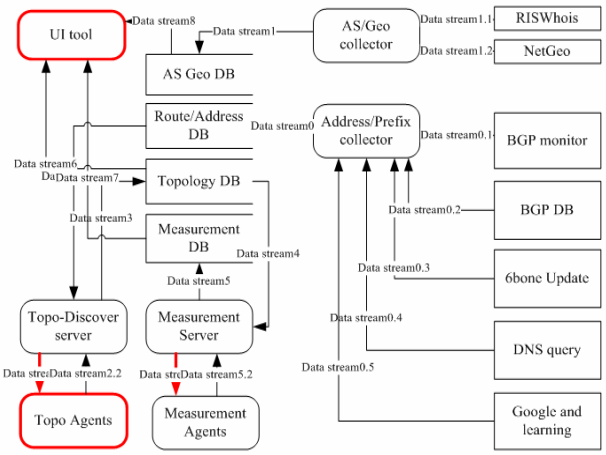


Figure 1. The system component of Dolphin system

Topology discovering is one main subsystem of Dolphin. It doses the work of probing the nodes of IPv6 Internet backbone and links between nodes, obtain other additional information of those nodes, such as geographic information and Autonomous system (AS). Topology discovering system takes a distributed architecture, which has a centre topology server and a number of topology agents. Those agents distribute in the IPv6 Internet, and do the probing work of IPv6 routers and route paths. Now Dolphin is configured with more than four agents connecting with IPv6 Internet on different countries of the world by 6over4 tunnels or pure IPv6 connection, and the number of agents and the connection to IPv6 Internet will be changed according to the status of IPv6 Internet. Table 1 shows that four tunnels used by Dolphin's agents and figure 2 displays the structure of topology server and agents.

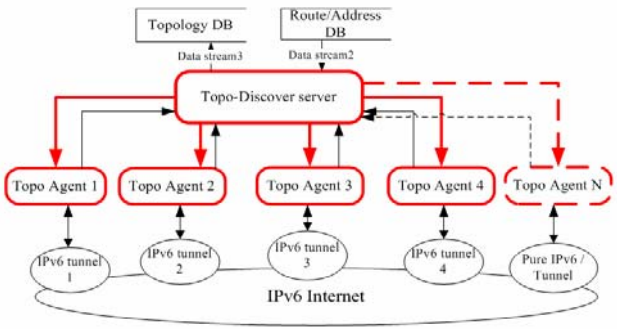


Figure 2. The distributed structure of topology center server and agents.

ID	IPv4 Addr.of Tunnel	AS	Country
1	202.38.99.4	AS4538	China
2	202.255.45.5	AS7667	Japan
3	139.18.25.33	AS680	German y
4	192.88.99.1	Dynamic	Dynamic
…	…	…	…

Table 1. The table of tunnels adopted by Dolphin system in topology discovering.

3. The topology probing methods and information collected by Dolphin

Dolphin system probes the network topology by active probing. Agents send probe packages based on ICMPv6. The basic probing process is that the Agent first sends a series ICMPv6 packages to a destination IPv6 address with an increased hop limit number, just like what traceroute tool does. And those ICMPv6 packages are set with an unreachable port number, so the routers on the path will return a port unreachable ICMPv6 packages to the agent (Not an ICMPv6 time-out package adopted by general traceroute tools). A completed probing process to a destination address can return us a router path to a destination address, which includes the router nodes on the path. Thousands of probing processes to hundreds of destination IPv6 addresses will return us the main shape of IPv6 Internet topology map.

The IPv6 addresses space is an increasing space which can not be probed completely, but it's still possible to probe the topology map of IPv6 backbone with a limited but represent able IPv6 destination address space. So, the integrality of topology map collected by Dolphin lies on two factors. First one is that Dolphin needs to prepare a perfect list of IPv6 destination address in advance, which can cover the whole IPv6 backbone and be updated on time. Second one, Dolphin needs to distribute its collection agents more widely as possible in the space of IPv6 Internet, which can help to fix some problems caused by centre structure agents, for example, the cross-link problem.

Dolphin system prepares its IPv6 destination address list from several different sources. The first one is BGP route prefix. Dolphin system develops a daemon tool which can monitor the BGP broadcast of IPv6 backbone, and then assemble the prefixes of IPv6 subnet to the relational IPv6 addresses. The 6bone's database of member's registered IPv6 addresses is the second source of IPv6 address list. Dolphin system finds about eight hundred available IPv6 addresses from this source. The third source is from some open IPv6 DNS database, such as http://IPv6.loercks.net [5]. From those databases, now Dolphin can get more than seven thousand couples of IPv6 address and Domain name. Dolphin system develops four agents which will timely update their address list

from those sources. So Dolphin system will keep the IPv6 destination address list to be upgraded on time. Table 2 displays the current status of different IPv6 address list sources.

Index	Source	The number of Destination IPv6 Address
1	BGP Pefix	About 900
2	6bone	About 800
3	DNS DB	About 7,000
4	Others	Dynamic

Table 2. The overview of different source of IPv6 destination addresses list.

4. The Collection of AS information and Geographic information

In addition to the topology discovering of route IP addresses level, Dolphin system also try to draw the topology map of IPv6 backbone on the Autonomous System (AS) level. Dolphin restore the topology map of AS level after cast back IPv6 addresses of IPv6 backbone topology to right AS number, and then draw the AS level topology map according to the available AS nodes and links on the IPv6 backbone topology. The transformation from IPv6 address to AS number is worked on the database of RISwhois[6], which can resolve 97% IPv6 addresses to available AS number. Also, Dolphin system query the geographic information of AS with NetGeo[7] tool. Because NetGeo tool is not updated real-time, so there're still about 9% AS codes collected by Dolphin system which can not be resolved to available geographic information.

With the help of above collected information, Dolphin builds and releases the AS-level geographic topology map of IPv6 on its web site.

5. Data Analysis and Present

Now, Dolphin system daily releases and updates all of its measurement data by Web. The topology server of Dolphin system can finish one time of topology scanning for whole IPv6 backbone within 4 or 5 hours, and finish a whole IPv6 backbone's bandwidth measurement within about 48 hours (Because the measurement of bandwidth need system to send a super larger probing packages which can't be done within a short time). Figure 3 display the trend map of the number of IPv6 routers, addresses and route paths which were daily discovered by Dolphin system. According to Dolphin system's result, in the past year, the number of IPv6 backbone router addresses has increase more than 700%, and the number of active AS number has increased from 215 to 468, about more than 200% increase. But we can notice that the greatest increase appear to be the link within the next generation Internet. The increase of the number of link in the past one year is close to 3000%. That's another factor of that the next generation Internet have largely enhanced its connection between each countries and organization. A large number of new route path and fresh connections has joined in the past year. A tightness IPv6 Internet is being under shaping.

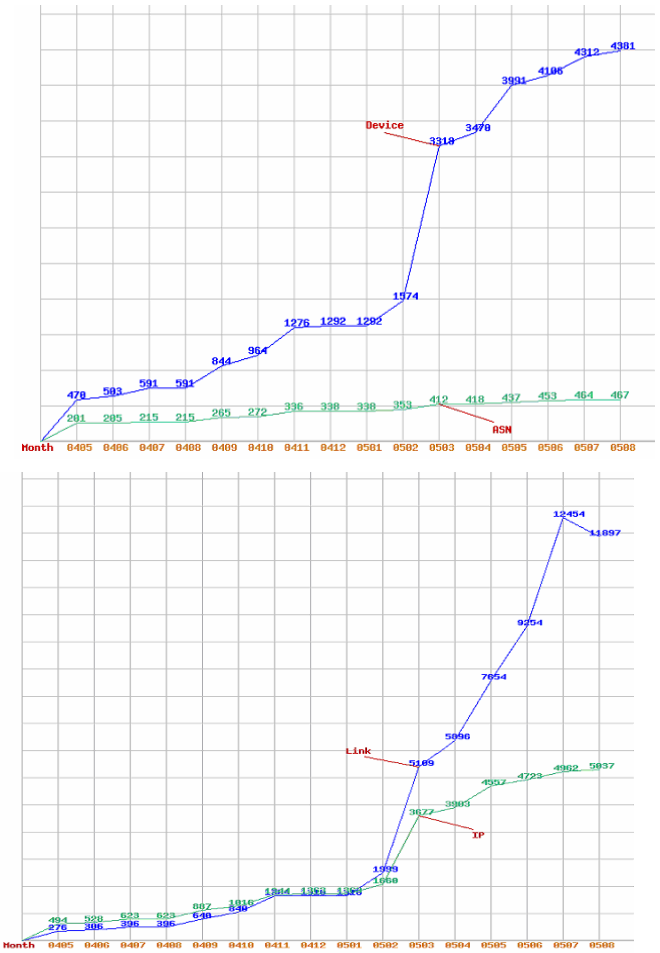


Figure 3. The trend map of the number of IPv6 routers addresses and route path (Link), which were daily discovered by Dolphin system. (Aug. 2005)

But Dolphin's result also tells the unbalanced development between countries and continents, just like current Internet based on IPv4. But many countries have many more chances to join the next generation Internet and take up the field for themselves in the future. From figure 4 and 5, we can notice the next generation Internet is main distributed on three countries and area. The distribution of IPv6 Internet is much more average in Europe than other continents.

American and Japan becomes two leader countries in the first stage of the next generation Internet. As figure 5 displays, the total link (In/Out) number of American and Japan almost closes to 50% of the whole IPv6 backbone. The multi culmination Internet should be modeled based on the overbalance of current IPv6 Internet.

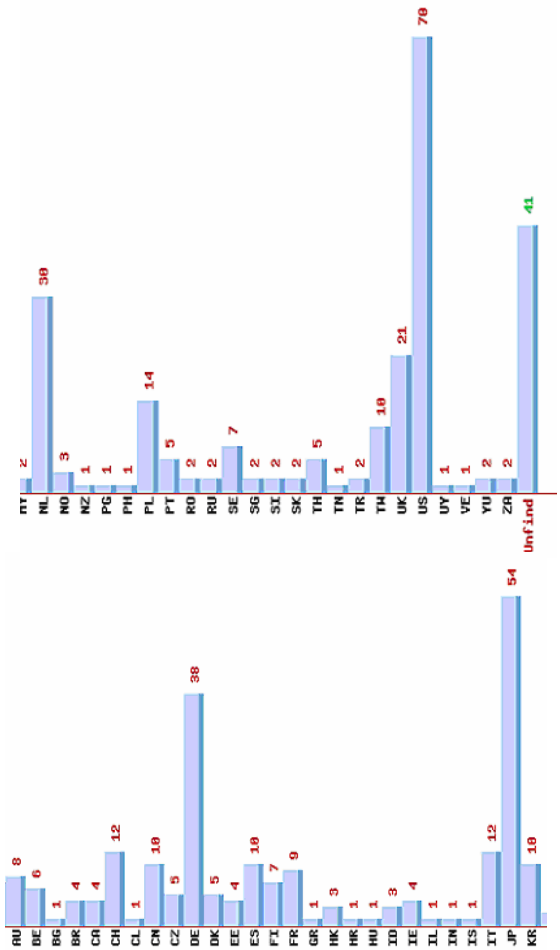
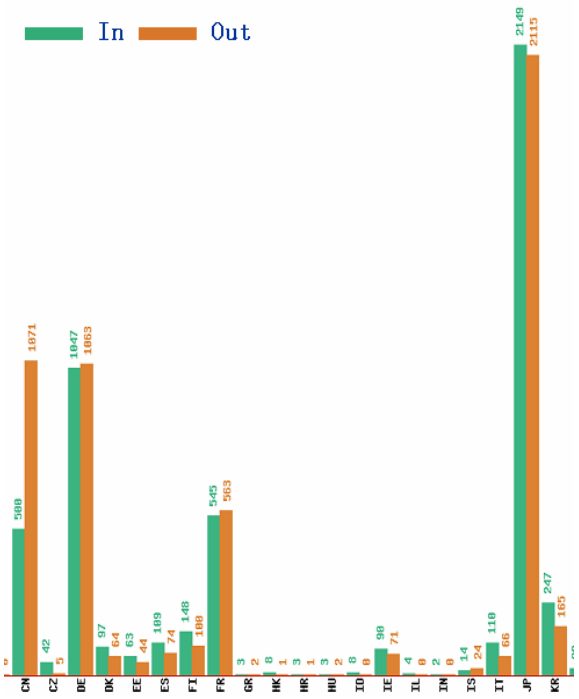


Figure 4. The distribution map of AS based on countries. (Aug. 2005)



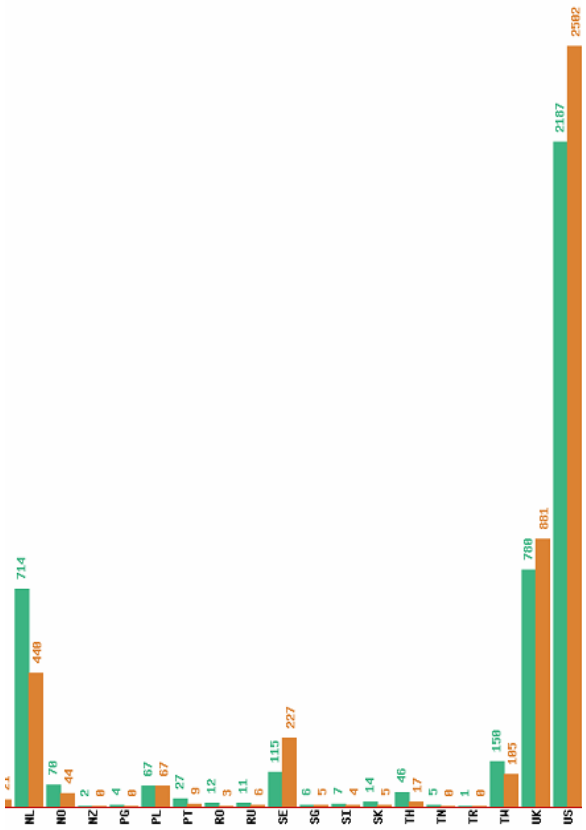
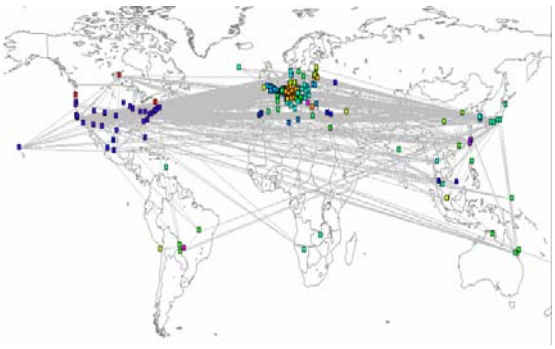


Figure 5. The overview of the distribution of route link (in/out) based on countries. (Aug. 2005)

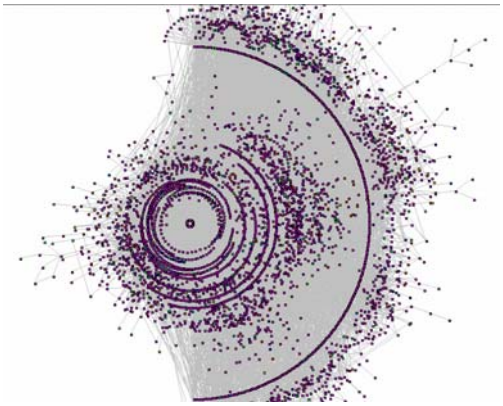
Dolphin system use more than four different connections with IPv6 Internet to find 468 AS within its topology map of IPv6 Internet, which cover the 85% of the current whole AS which number is 550 according to the latest AS Statistical Information collected by 6bone [8][9]. Table 3 lists the statistic information of current IPv6 Internet collected by Dolphin, and the statistic information collected by CAIDA is also list to be referenced. Dolphin develops its topology display tools based on Otter tool [4] developed by CAIDA. The geographic AS-level topology map and router IP level topology map drawn with the data from Dolphin are displayed in Figure 6.

	Dolphin	CAIDA
Last update time	Aug.13,2005	March 4th,2005
AS number	468	333
IPv6 addresses	5,191	2,913
IPv6 links	11,665	7,905
Monitors	4	17

Table 3. The statistic information of the IPv6 Internet collected by Dolphin and CAIDA. (Aug. 2005)



The geographic AS-level topology map of IPv6 Internet



"Root" layout of Route IP-level topology map

Figure 6. The geographic AS-level topology map & Route IP-level topology map with "Root" layout algorithm. The data is collected by Dolphin system.

6. Conclusion and future work

Though, the next generation Internet gains a super high speed on its development, but the existed scope of IPv6 Internet still can be mentioned in the same breath with current IPv4 Internet. According to the latest statistic information of current Internet released by CAIDA, there're 12,979 Autonomous System (AS) on its AS-level topology map, and The IP addresses-level topology graphic reflects 926,201 IP addresses and 2,000,796 IP links [4]. So, although the next generation Internet can provide 296 times the IP addresses of current IPv4 Internet in theory, the existed scope of IPv6 Internet is very limit compared to current Internet. So, though there're some systems like Dolphin which can perfectly probe the current IPv6 Internet, there're still exist many problems about how to measure or probe the information of next generation Internet, the super large IP address space and the flood tide router entry will become the real troubles faced by Internet measurement. Now, Dolphin system focus its future work on the smart agent based measurement architecture and tries to resolve the problems which will be introduced by the future of next generation Internet.

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