High-energy Efficient Layer-3 Network Architecture based on Solitary Universal Cloud Router and Optical Aggregation Network

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Abstract:
This paper proposes high-energy efficient future-Internet architecture. All traffic is aggregated to a solitary universal cloud router through an optical aggregation network. Evaluation shows power consumption can be reduced to 1/1000 compare to present Internet.

1. Introduction
The internet subscribers have been increasing 15% every year. At the end of 2009, it grew up 1802 million users [1], and the Internet traffic has been increasing dramatically too, and real-time traffic and routing statistics reaches about 14 Tbps [2].

According to the progress of Internet, the power consumption of network equipments has been increasing rapidly. The power consumption of ICT has been increasing about 8% every year. In 2008, the ICT power consumption grew 168 GW, in 2020 it will be 430 GW (about 2.6 times) [3]. The power consumption of network equipments has been increasing about 12% every year. In 2008 it was 25 GW, in 2020 it will grow 97 GW (about 4 times) [3]. The power consumption of Internet depends on the network structure.

The network structure of Internet is very redundant. Because the Internet is a cluster structure that consists of a large number of AS, the Internet can be seen as one large packet switch, where many extra switches and routers exist. It means that we do not use the capability of router’s switching-capacity fully and do not optimize the network structure.

The number of hops is large, so RTT and timing jitter are also large. The average of the number of hops is about 12 hops in Asia, Europe, USA [4]. RTT of 12 hops is about 300 ms at probability 90% and the average RTT during from 14 hops to 19 hops is about 600 ms at probability 90% [5]. Large RTT makes interactive communication service degrade. General speaking RTT over 300 ms - 400 ms makes natural conversation impossible.

Large delay jitter degrades the quality of streaming service, VoIP and Tele-conference, movie. The data packets’ delay jitter makes packet-loss and memory buffer overflow, so original voice and picture cannot be restored without defects.

The traffic of Internet is centralized to backbone network. There are two reasons.

One is Hyper Giants make peer connection without through Tier1 provider. In 1995-2007, contents providers and CDN groups connected through Tier1 provider, but they connect through Tier2/Regional provider, now [2].

Google and Yahoo are Hyper giants contents provider and Level3 and akamai are Hyper Giants CDN groups. They connect through Tier2/Regional. Hyper giants are about 30 companies and they occupy 30%. of Internet traffic worldwide [2].

The other is cloud computing, it has been magnifying rapidly, so the traffic to data center has been concentrated in backbone network.

This paper proposes a high-energy efficient network architecture using optical aggregation network and a large scale solitary universal cloud router in data center.

The proposed network architecture, all IP traffic is aggregated and transferred to data center where a layer-3 switch is performed. Data center consists of Solitary Universal Cloud Router and application servers. Solitary...
Universal Cloud Router is power scalable with an amount of traffic proportionally.

2. Power consumption of routers and optical switches

The power consumption of routers depends on switching capacity beyond about 30 Mbps without the power consumption of line-cards. The power consumption of routers is shown following equation [4].

\[ P = C^{2/3} \]

- P: Power consumption (watt)
- C: router switching Capacity (Mbps)

This equation indicates that the power consumption per bit becomes smaller as the switching capacity increases. For example, in case of 1Tbps-capacity, we need 1 Gbps-router 1000 sys and the power consumption is 100 KW, and we need 1 Tbps-router 1 sys and the power consumption 10 KW. So, 1 Tbps-router can reduce the power consumption 1/10 compare to 1000 1 Gbps-routers.

An optical switch contributes the reduction of the power consumption due to switching equipments drastically. At 100 Tbps switch, the power consumption of MEMS-based circuit switch with wavelength converters is about 1/160 of the power consumption of an electric packet switch [6], and MEMS-based circuit switch without wavelength converter is about 1/500 of the power consumption of the electric packet switch [6].

3. Service Cloud and Optical Aggregation Network

This paper proposes high-energy efficient future-Internet network architecture as shown in Fig. 1. Routers and servers are integrated and installed in backbone network. Data center consists of Solitary Universal Cloud Router and application servers. Optical Aggregation Network consists of optical circuit switches and wavelength converters. All IP traffic is aggregated and transferred through Optical Aggregation Network to data center where a layer-3 switch is performed. So, a simple 1 hop network is realized.

As shown in Fig. 2, Optical Aggregation Network consists of multiplexers/demultiplexers with optical switches and wavelength converters. Optical Aggregation Network transfers consumer data on optical resources with optical slots and wavelength transparently. Solitary Universal Cloud Router is power scalable with an amount of traffic proportionally.

4. Evaluation of power consumption

The comparison model is shown in Fig. 3.

Model A is the present Internet. The present Internet router network model consists of 100 Gbps-routers which are interconnected with mesh and 100 Gbps-routers has GE 100 ports.

Model B is simple aggregation. Routers are aggregated to one large scale router simply, so one large scale router has extra switching capacity. Optical Aggregation Network consists of optical multiplexer/demultiplexer switches which multiplex 100 to 1 and demultiplex 1 to 100. An optical switch is circuit switch with wavelength converters.

Model C is strict aggregation. Model C is proposed
network structure. Optical Aggregation Network structure is as same as Model B, and the router switching capacity is 15 % of that of Model B. Solitary Universal Cloud Router operates with full switching capacity, so there is no extra capacity in the router switch.

The evaluation of power consumption is shown in Fig. 4. Model A graph shows power consumption is 26 KW at 1-100 GE ports and 2.6 GW at 10M GE ports. Model B graph shows that power consumption is 2 KW (GE:1-100 ports) and 6 MW (GE:10 Mports). Power consumption can be reduced to 1/12 (GE:100 ports) and 1/430 (GE:10 Mports) compare to Model A. This power reduction is mainly the effect of the Optical Aggregation Network, and the effect of router aggregation and integration are not so big.

Fig. 3 Power consumption evaluation model.

Fig. 4 Evaluation of power consumption.

5. Conclusion
This paper has proposed high-energy efficient future-Internet consists of Optical Aggregation Network and data center which consists of Solitary Universal Cloud Router and application servers. All traffic is aggregated to Solitary Universal Cloud Router through Optical Aggregation Network. Evaluation shows the proposed network power consumption can be reduced to 1/1000 drastically compare to present Internet.

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Reference