Development of the Public Internet Exchange (PIE) in Thailand

Chalermpol Charnsripinyo, Angkana Angkalukkana,
Thaweesak Koanantakool, Pornthep Narula

Abstract --An Internet exchange is defined as a high-speed network or switch serving as an interconnection point for traffic exchange among Internet Service Providers (ISPs). Many countries have tried to set up their local Internet exchanges to reduce the operating cost of ISPs due to the expensive international links.

This paper describes development of the Public Internet Exchange (PIE) which is one of the two local Internet exchanges in Thailand. All aspects of PIE including history, current status, architecture, sample traffic statistics, problems, and policy are mentioned in details.

keywords: Internet Exchange, Thailand, PIE, Public Internet Exchange, Internet, Internet Service Provider, NECTEC, CAT

บทคัดย่อ-- ศูนย์แลกเปลี่ยนข้อมูลอินเทอร์เน็ต หมายถึงเครือข่ายหรืออุปกรณ์ที่ทำหน้าที่เป็นจุดเชื่อมต่อระหว่างผู้ให้บริการอินเทอร์เน็ตต่างๆ เพื่อให้สามารถทำการรับ-ส่งข้อมูลระหว่างกันได้ ซึ่งหลายประเทศได้พยายามจัดตั้งศูนย์แลกเปลี่ยนข้อมูลอินเทอร์เน็ตภายในประเทศขึ้นเพื่อช่วยลดต้นทุนในการดำเนินการของผู้ให้บริการอินเทอร์เน็ตในด้านการใช้งานวงจรสื่อสารระหว่างประเทศ

รายงานฉบับนี้เป็นการอธิบายถึงการพัฒนา ศูนย์แลกเปลี่ยนข้อมูลอินเทอร์เน็ตสาธารณะซึ่งเป็นหนึ่งในสองศูนย์แลกเปลี่ยนข้อมูลอินเทอร์เน็ตของประเทศไทย โดยจะได้กล่าวถึงความเป็นมา สถานะปัจจุบัน สถาปัตยกรรมของระบบ ตัวอย่างสถิติการใช้งานอุปสรรคและวิธีการป้องกันและแก้ไข รวมทั้งนโยบายการพัฒนาและบริการโดยละเอียด

คำสำคัญ: ศูนย์แลกเปลี่ยนข้อมูลอินเทอร์เน็ต, ประเทศไทย, PIE, ศูนย์แลกเปลี่ยนอินเทอร์เน็ตสาธารณะ, อินเทอร์เน็ต, ผู้ให้บริการอินเทอร์เน็ต, ศูนย์เทคโนโลยีอิเล็กทรอนิกส์และคอมพิวเตอร์แห่งชาติ, การสื่อสารแห่งประเทศไทย

Introduction

The Internet is known as a worldwide computer network. It consists of networks of networks connected together with various media and protocols. Almost every country that has Internet connections has dedicated circuits to different ISPs in the United States. Therefore, data traffic exchange among many networks happens in the US. This is the burden of ISPs due to the cost of international links. To save operating costs, many countries are currently running their own exchange points for local traffic exchange.

The situation of the Internet development in Thailand was quite similar to several other developing countries. Most Thai ISPs have their own overseas links to the US. The intra-country traffic among networks in Thailand had to go through exchange points in the US that increased the operating cost of Thai ISPs. This resulted in the set up of local Internet exchange points in Thailand. The success story of Internet development and the setting up of the Public Internet Exchange in Thailand will be given in this paper.

The history of Internet development in Thailand

Development of the Internet in Thailand began with a group of university professors who would like to keep contact with friends and researchers in other countries. In 1987, the Prince of Songkhla University (PSU) set up the first email connectivity to the University of Melbourne, Australia.

At the same time, the Asian Institute of Technology (AIT) tested UUCP connections to the University of Melbourne and the University of Tokyo via the Communication Authority of Thailand (CAT) X.25 service. All initial connections were based on dial-up links to those universities. In early 1988, the Thai Computer Science Network (TCSNet) was founded with support from the Australian government, through the Australian International Development Plan (IDP). Three universities that are PSU, AIT and

Chulalongkorn University (CU), initially joined the TCSNet. Later on In 1991, Thammasat Unversity (TU) installed MHSNet software and a 14.4 kbps modem with support from the Australian Academic and Research Network (AARNet) and became a new gateway for Thailand's academic and research institutions to communicate with University of Melbourne. The electronic mail service via MHSNet and UUCP became an important tool for Thai academics at the time.

Apart from the aforementioned universities, the National Electronics and Computer Technology Center (NECTEC) was running another Inter-University Network over X.25. The Inter-University Network project was identified since 1987 as an academic and research network focusing on the key issues of telecommunication infrastructures and databases. In January 1992, an electronic mail committee called NEWgroup (NECTEC's Email Working Group) was set up to represent demanding users to interact with NECTEC. This resulted in the permanent set up of the Thai Social/Scientific, Academic and Research Network (ThaiSarn) which was the merger of TCSNet and the Inter-University Network.

ThaiSarn was initially funded by the national budget via NECTEC and was technically supported by NECTEC's in-house Network Technology Laboratory (NTL), founded in April 1992 to look after the services and technical aspects of this network. Since the world-wide Internet were mainly based on the Internet Protocol (IP) technology and had very high growth rate at the time, NECTEC decided that ThaiSarn should also migrate to full Internet Protocol. Therefore, the early-day MHSNet and UUCP dial-up links as well as X.25 were gradually replaced by full fledged TCP/IP links on leased lines, while new nodes were added. The first 9.6kbps international gateway was the link between CU and UUNET in 1992. Shortly after that, another 64 kbps international line was launched between NECTEC, the hub of ThaiSarn, and UUNET.

All institutions linked to ThaiSarn have to abide by ThaiSarn Acceptable Use Policy (ThaiSarn AUP). Not only academic institutions but also many government agencies used ThaiSarn services. In 1994, some schools began to test Internet connections. Prototype nodes for schools started connecting to ThaiSarn. This resulted in the set up of the SchoolNet project by NECTEC in 1995, Thailand's IT Year.

Internet on the nonacademic side also began in 1995. After six months of feasibility study by a joint working group, the Communications Authority of Thailand (CAT) and the Telephone Organization of Thailand (TOT) approved a joint venture proposal from NECTEC to commercialize of the Internet in Thailand. Internet Thailand Company Limited, jointly invested by NECTEC, CAT, and TOT, received the first operating licence from CAT. The Internet Thailand Company launched its full-scale services with its first 512 kbps international gateway through UUNET, VA, USA in March 1995. Almost at the same time, KSC Comnet also received an operating licence from CAT and became Thailand's second commercial Internet Service Provider (ISP). A few months later, CAT approved proposals from Loxley Information and other two companies for operating license. The Internet usage and connectivity had continued to grow since then. A number of ISPs was later established to provide Internet services nationwide for both corporate and individual subscribers.

Current status of Internet in Thailand

As of October 1998, ThaiSarn, the biggest academic and research network in Thailand, has been expanded to cover almost all state universities nationwide. There are 66 nodes connected to ThaiSarn. Major universities are connected with 2 Mbps (E1) links and many institutions are connecting with 64 - 512 kbps links. The total domestic bandwidth of ThaiSarn is currently above 17 Mbps. ThaiSarn has a 2.5 Mbps gateway to the global Internet via Internet Thailand, and another 2 Mbps link to the National Center for Scientific Information System (NACSIS), Japan, for communication between ThaiSarn and SINET, Japanese academic network. Apart from ThaiSarn, some universities also have direct domestic and international links to ISPs.

The SchoolNet@1509 project that provides free dial-up Internet access to schools has been expanded to cover schools nationalwide. With support from TOT and CAT, NECTEC finished the initial phase of SchoolNet project with 20 POPs in March 1998. There are more than 80 schools using the service. With minimum of personnel and resource, the project started with the philosophy of "equal" minimum accessibility for all. The network will later be upgraded to meet the real demand. It is expected to reach 2500 schools by the end of 1999.

On the non-academic side, Thailand currently has fifteen ISPs operating nationwide. Most of them have their own international links to their upstream ISPs in the US. In July 1996, CAT started providing its own wholesale Internet service, called the International Internet Gateway (IIG), which resells its international Internet bandwidths to local ISPs who cannot afford their

own international links. Some small ISPs use CAT's IIG service to save the cost of operations. Nevertheless, most ISPs still prefer to have their own international lines due to reliability and competition. The combined international link capacity is above 30 Mbps (see http://www.nectec.or.th/inet-map/).

Setting up of Internet Exchanges in Thailand

Before the existence of local Internet exchange points in Thailand, all ISPs and their customers have to communicate with each other via their overseas links. Almost all international lines are linked to different ISPs in the United States. With limited bandwidths of international links that is expensive and relatively slow, the burden from intra-country traffic via overseas links was apparent.

Thailand National Internet Exchange (NIX) was first set up by CAT for exchanging domestic traffic among Thai ISPs after CAT started operating the Internet IIG) service in July 1996. IIG and NIX were linked locally by a 10 Mbps Ethernet cable and later upgraded to a 100 Mbps link. Major ISPs have at least a 512 kbps link to NIX and pay CAT a monthly maintenance fee for the service.

The ThaiSarn Public Internet Exchange (PIE) was set up by NECTEC in November 1997. It was set up as a peering point for Thai ISPs to access public information on the ThaiSarn Public access Network (PubNet), a network of national servers such as FTP, Web, Gopher, Cache, News, Media servers, etc. In addition, it plays a significant role as the alternative exchange point with CAT's NIX to alleviate the single point of failure. Since all ISPs are required to use CAT leased-lines to connect to NIX while PIE allows ISPs to use any other circuit providers' services, such as TOT, TelecomAsia (TA), etc., a failure in one of the telecom infrastructure will not paralyze the others.

PIE is operated by NTL and located at NECTEC's network hub that permits broadband interconnection to PubNet, ThaiSarn, SchoolNet@1509, Kanchanapisek Network, and government networks. In the first year, NECTEC fully subsidizes the operating cost including electricity and a rack space at PIE. NTL assures that all PIE participants are given equal opportunities to access all information servers and networks connected to NECTEC hub.

At present, NIX and PIE are linked with a 2 Mbps leased circuit. There are eight and ten ISPs connecting to NIX and PIE, respectively. Five of these are connected to both exchange points. However, there are three ISPs that have not yet connected to any local exchange points.

The following table shows the date and link speed of each ISP connected to NIX and PIE.

Internet Service Providers and NIX	NIX		PIE	
	Date Connected	Current link speed	Date Connected	Current link speed
A-Net Co., Ltd.	Feb 4, 1998	512k	Jan 26, 1998	512k
Asia Access Internet Service	-	-	Dec 24, 1997	
Asia Infonet Co.,Ltd.	-	-	Dec 30, 1997	512k
C.S. Communications Co.,Ltd	Oct 21, 1997	512k	May 25, 1998	256k
Chomanan Group Co., Ltd.	-	-	-	-
Data Line Thai Co., Ltd.	Aug 10, 1997	64k	-	-
Far East Internet Co.,Ltd.	-	-	Jun 16, 1998	128k
Infonews Co., Ltd.	-	-	-	-
Internet Thailand Service Center	Nov 11, 1996	512k	Nov 15, 1997	10,000k
KSC Commercial Internet Co., Ltd.	Aug 22, 1997	2,048k + 512k	Jun 24, 1998	1,024k
Loxley Information Service Co., Ltd.	Feb 5, 1998	2,048k	Apr 17, 1998	512k
Samart CyberNet Co., Ltd.	-	-	Dec 3, 1997	1,024k
Siam Global Access Co.,Ltd.	N/A	512k	Oct 26, 1998	128k
WorldNET & Services Co.,Ltd.	Sep 27, 1997	512k	-	-
NIX	N/A	N/A	Jun 11, 1998	2,048k

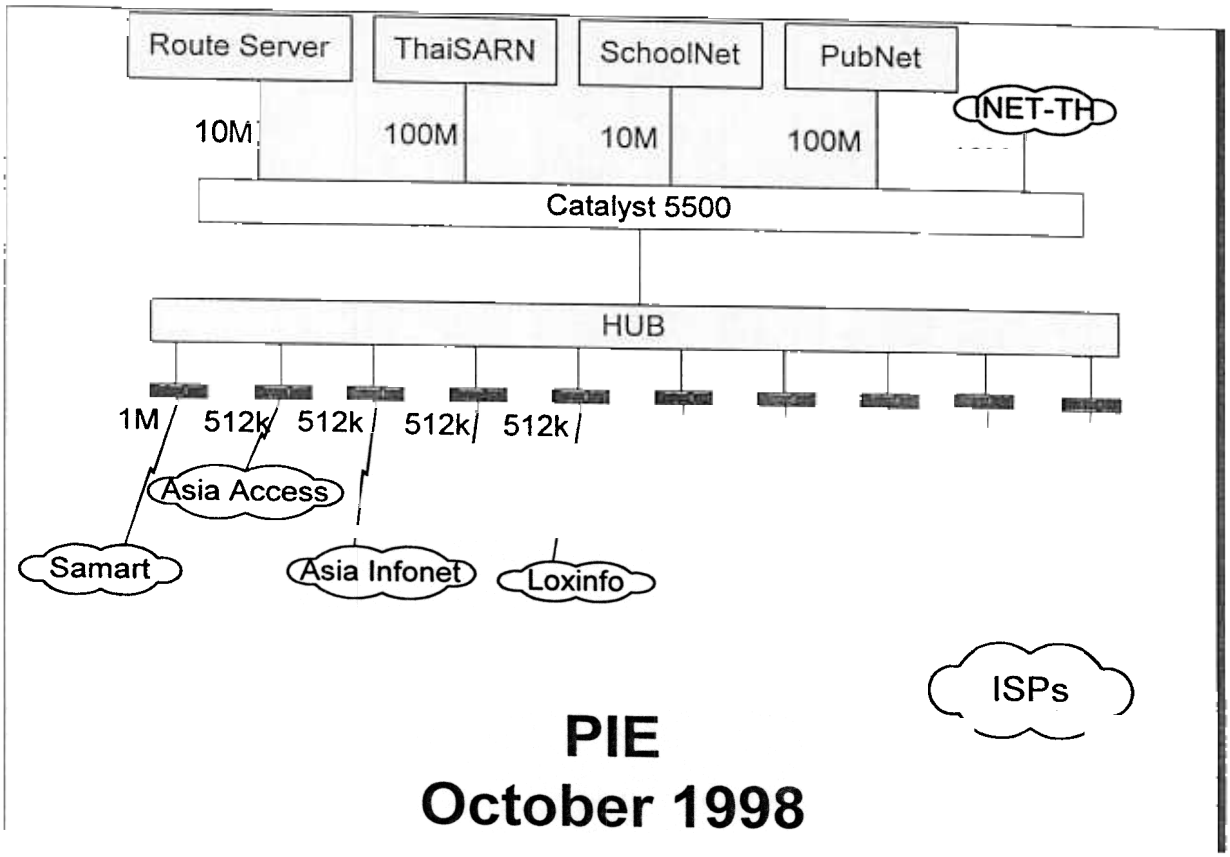
Technical aspects of PIE

PIE's backbone is currently a simple network connecting participants' routers together. Each participant rents its own dedicated circuit at the desired speed of a minimum 128 kbps to PIE and places a router there. All participant's routers are linked together with Ethernet interface at the speeds of 10 or 100 Mbps. Initially, NTL/NECTEC is supporting one 100Base-TX and twelve 10Base-T ports for founding members of PIE. A dedicated router is serving as the route server of PIE. A Cisco Catalyst 5500 LAN switch is used to link PIE to PubNet, ThaiSarn, and SchoolNet at the speed of 100 Mbps. (See diagram)

The route server is the center of routing updates processing for all participants's routers to eliminate the load of multi-sessions route-exchange peering. Routing information is exchanged by means of the BGP-4 routing protocol. Each participant must announce all routes of its entire autonomous systems and its domestic downstreams. The route server will re-broadcast the entire routing entries and updates to all other routers in PIE. The current method to prevent incorrect routing information from propagating through PIE is the use of network access lists on the route server.

PIE Policies

PIE Pilot Project is part of the National Information Infrastructure action plan to support a strong, unified and most economical means for running the Internet in Thailand. It is planned to be a joint mission between Government, Academic/Research Institutions and the private sector.



PIE Project will ensure that all participants will be given equal opportunities to access the third-generation academic/research network "ThaiSarn-III", the Knowledge Distribution Network of the Kanchanapisek Network, and the public portion of the Government Information Network (GINet). PIE is initially funded by the Royal Thai Government, and is operated as a not-for-profit task of NECTEC.

Traffic to and from PubNet and ThaiSarn is provided for free to all PIE Participants (PIEPs) provided that it strictly abides by ThaiSarn Acceptable Use Policy (ThaiSarn AUP). Inter-ISP traffics may or may not follow ThaiSarn AUP; NTL does not concern or impose any restriction

over commercial traffic as long as it is not destined for or transit via ThaiSarn and/or PubNet. Violation to ThaiSarn AUP simply means the PIEP is terminated from PIE.

NTL, the Network Operating Center of PIE, will measure traffics of each PIEP. Should an incoming or outgoing traffic of a PIEP circuit exceed 60% average utilization for seven (7) consecutive days, the PIEP must upgrade the under-capacity link to meet PIE standard QOS.

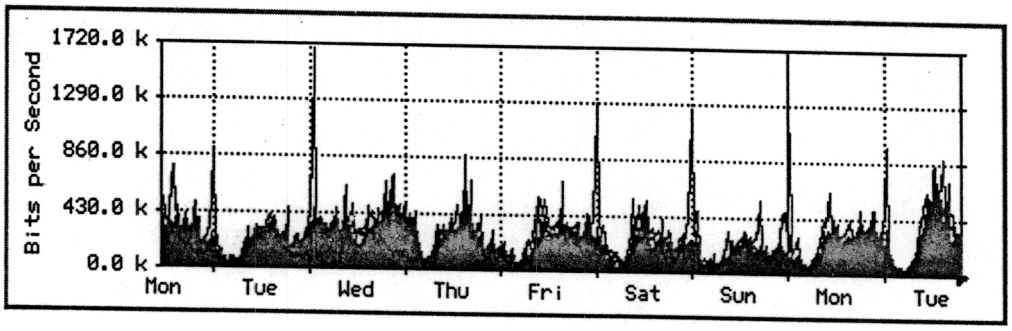
Connection to PIE Pilot Project is free of charge for one year. Eligible PIEP must have a valid Thai ISP licence granted by the Communications Authority of Thailand. Costing for further funding of PIE Project is subject to future government budget availability and the actual cost of previous year's support to each PIEP. However, the long-term service subject to future government budget availability and the actual cost of previous year's support to each PIEP. However, the long-term service charges (if any) will be based on costs and not-for-profit scheme.

Traffic statistics and analysis

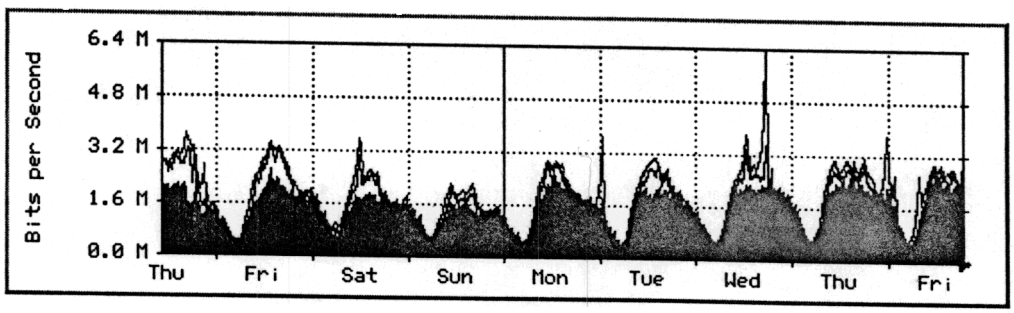
PIE is now operating in a fourteen-tiered fashion with ten ISPs, ThaiSarn, PubNet, SchoolNet@1509, and NIX. To monitor the traffics load on various network links, the Multi Router Traffic Grapher (MRTG) is installed on a unix machine and used to generate graphs representing the traffics on each monitored link into webpages.

The Graphs shown in the following figures are Weekly Traffic Graph (averaged every 30 minute) of PubNet, ThaiSarn and NIX connections to PIE, respectively. The green color (filled area) in the graph is the In-traffic to PIE and the blue color (Dark line) is the Out-traffic from PIE

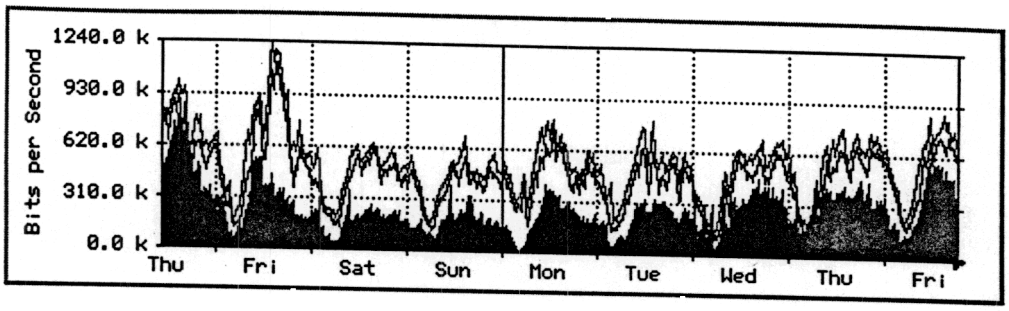
PubNet



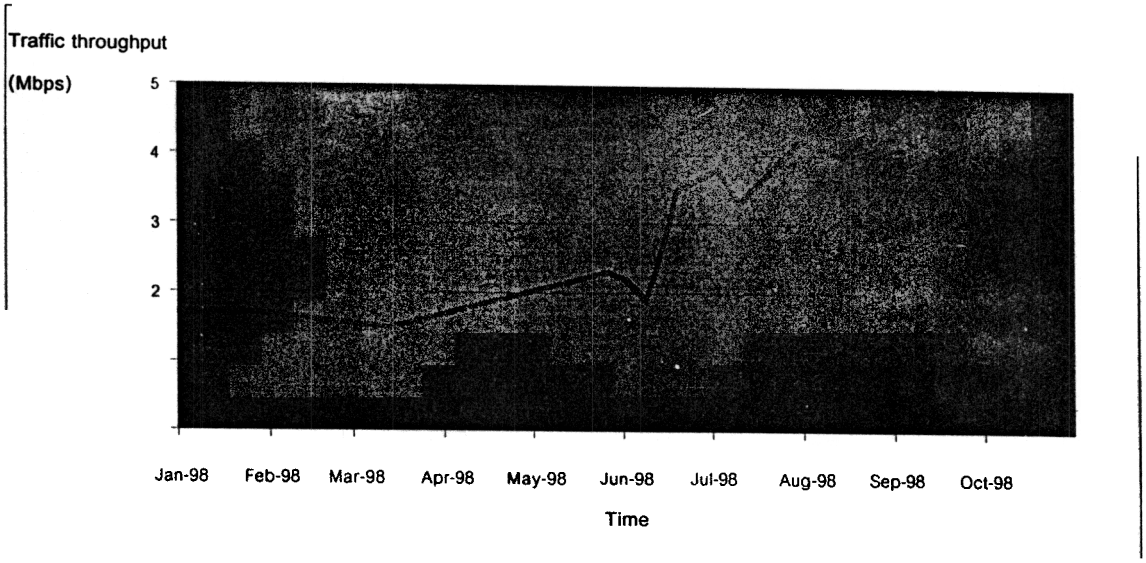
ThaiSarn



NIX



Traffic Growth



The following table shows PIE traffic Statistics in 8-day Average.

ISPs	traffic injected into PIE		Traffic taken from PIE		Line Utilization	
	kbps	Share	kbps	Share	To PIE	from PIE
InternetThailand	1174.7	26.0%	629.2	14.0%	11.7%	6.3%
Samart	346.4	7.7%	397.7	8.9%	33.8%	38.8%
AsiaAccess	42.4	0.9%	129.8	2.9%	8.3%	25.3%
AsiaInfonet	68.2	1.5%	170.9	3.8%	13.3%	33.4%
ANET	213.7	4.7%	337.8	7.5%	41.7%	66.0%
LoxInfo	0.3	0.0%	75.2	1.7%	0.1%	14.7%

CSComs	25.1	0.6%	104.2	2.3%	9.8%	40.7%
FarEast	9.7	0.2%	21.0	0.5%	7.6%	16.4%
KSC	465.0	10.3%	367.9	8.2%	45.4%	35.9%
SGA	22.5	0.5%	7.6	0.2%	17.6%	5.9%
NIX	475.3	10.5%	555.4	12.4%	23.2%	27.1%
ThaiSarn	1422.1	31.5%	1491.4	33.3%	1.4%	1.5%
PubNet	187.8	4.2%	130.9	2.9%	0.2%	0.1%
SchoolNet	62.8	1.4%	61.3	1.4%	0.6%	0.6%
TOTAL	**4516.1**		**4480.3**			

As can be seen from the graphs and table, the current traffic report as of Wednesday, 28 October 1998 at 17:30 can be summarized as follows:

TOTAL AVERAGE TRAFFIC CIRCULATION
4.5 Mb/s (full-duplex)
DAILY TRAFFIC VOLUME
46.3 GB
WEEKLY TRAFFIC VOLUME
324.3 GB
MONTHLY TRAFFIC VOLUME
1389.9 GB

marginal error of measurement (unbalanced sum) 0.1%

sampling interval 5 minutes through a 8-day window

Total traffic at the sustained transfer rate of 4.5 Mb/s is 46.3 GB per day.

From the traffic figures above, if we simply convert the average traffic volume 4.5 Mb/s to be bandwidths of international links based on QoS of 60% average utilization, we may need approximately a total of 7.5 Mbps for the purpose of traffic exchange among participants. That means PIE is helping saving the cost of 8 Mbps international bandwidth and providing faster domestic-traffic exchange for Thai ISPs.

The following table is percentage of time that each link connected to PIE failed (PIE Outage) during 21 April 1998 - 14 September 1998.

Internet Service Providers	Outage (%)						
	Apr	May	Jun	Jul	Aug	Sep	Average
Internet Thailand Service Center	0.00	0.03	0.00	0.00	0.00	0.00	0.005
Samart CyberNet Co., Ltd.	0.27	0.57	1.58	0.00	0.00	0.04	0.411
Asia Access Internet Service	1.37	0.17	0.71	0.18	0.22	0.14	0.463
Asia Infonet Co., Ltd.	0.20	1.92	0.00	0.00	0.00	0.02	0.356
A-Net Co., Ltd.	0.00	5.95	0.42	0.69	5.15	0.04	2.041
Loxley Information Service Co., Ltd.	0.00	0.09	0.00	1.06	0.19	0.04	0.231
C.S. Communications Co., Ltd	-	0.01	0.47	0.05	0.11	0.12	0.152
Far East Internet Co.,Ltd.	-	-	0.04	0.00	0.00	0.04	0.005
KSC Commercial Internet Co., Ltd.	-	-	0.00	0.02	0.29	0.05	0.090
NIX	-	-	-	0.16	1.32	0.00	0.493

Problems and Challenges

Like several Internet exchanges in other countries, PIE is not without problems. The idea of setting up PIE is by chance synchronous with

several ISPs' desires to have an alternative Internet exchange to prevent a single point of failure from NIX. PIE is currently a pilot project supported by NTL/NECTEC. CAT also connects NIX to PIE with a 2 Mbps link for the purpose of traffic exchange between two Internet exchange points. It is the challenge to prove that should Thailand have two internet exchange points.

On technical side, we have policy that PIE participants must announce full routes to PIE but we currently do not have a mechanism in place to verify this. When an ISP mistakenly announces problematic routes, say a subnet owned by another ISP, it creates wrong routes on PIE. The administrators of PIE won't know the problem until there is complaint from the affected parties. To solve the problem, we have to know which

networks belong to whom. The Routing Arbiter Database (RADB) and related tools are being studied to manage routing policy on PIE.

Future Plan of PIE

To date, PIE is still in its infant stage. The backbone of PIE is a simple network and the service is free of charge. However, NTL/NECTEC plans to improve PIE to be a mature exchange point of Thailand after the one-year pilot project. Three main issues are under discussion for future development of PIE.

First, on the network issue, PIE will continue as a simple network with the replacement of 10 Mbps hubs by 10/100 Mbps Ethernet switch. The link between NIX and PIE will be upgraded to meet PIE QoS and support heavy traffic between two domestic exchange points. New technology such as ATM technology will be studied and tested by NTL to prepare for the high-speed network service in the future.

Next, on the operation and service issue, new softwares and tools are being studied and will be implemented to improve PIE operations and services. The Routing Arbiter Database (RADB), RAToolSet and Route Server (RS) are being studied to see if they are suitable for PIE. New programs for traffic statistics and analysis are to be developed to provide advance services.

Last but not least, on the policy issue, funding models to support PIE after the end of the one-year pilot are being explored. As from November 1, 1998, it will be run by "cost-sharing-model" based on the total expenses of the previous year. It was planned to be a totally non-profit service. However, it may not cost anything to the taxpayer either. The format of consortium would possibly be established to ensure the survival of PIE . NTL/NECTEC is still the neutral party for PIE and will continue to support PIE operations. Nevertheless, the aforementioned issues for the future of PIE are to be presented among PIE participants for further discussions.

Conclusion

The Internet is too big and important to be controlled or governed by any single organization. When the Internet growth in a country reaches a certain state, a way must be found to organize the networks so that it can survive and keep growing. Setting up local Internet exchanges in each country is one way to reduce the unnecessary load on international links and the complexity of network topology.

For the situation in Thailand, the Communications Authority of Thailand (CAT), who regulates Internet in Thailand, first set up Thailand National Internet Exchange (NIX) in July 1996. In November 1997, Network Technology Laboratory (NTL) of the National Electronics and Computer Technology Center (NECTEC), which took part in the development of the Internet in Thailand from the beginning, set up Public Internet Exchange (PIE) as the alternative domestic exchange.

PIE is considered a successful project from its very beginning. The reasons may be ascribed as follows:

- It is the access point to PubNet that provide many free services to the public. ISPs have gained a great benefit from PubNet services.
- It is located at the networks hub of Thailand. ThaiSarn, SchoolNet, PubNet, and PIE are linked together at 100Mbps. Therefore, it provides faster services to PIE.
- It is operated by a neutral party with experienced staffs. NTL/NECTEC is perceived as an appropriate party because NTL is a research laboratory. it does not provide commercial Internet services. In addition, NTL/NECTEC has set up and managed major networks in Thailand.
- It is a low-cost service. Besides small investment in a small router and monthly fee for the leased circuit, participants do not have to pay any service fee to PIE in the first year.
- It satisfies ISPs' requirement as the alternative exchange point with good management and service. PIE provides traffic statistics, mail alerts, and QoS control for all participants.
- All participants have gained benefits from PIE broadband interconnection to national networks.

To date, NIX and PIE are the two local Internet exchanges in Thailand. All parties, both ISPs and Internet users, have gained significant benefits from the local exchanges. However, problems on NIX and PIE must be solved. NIX and PIE will continue to evolve in order to survive and support Internet growth in the future.

References and Future Updated Information

- The Internet Connectivity Map of Thailand: see "http://www.nectec.or.th/inet-map/".
- The SchoolNet Thailand project : see "http://www.school.net.th/".
- The Thai Social/Scientific, Academic and Research Network (ThaiSarn): see "http://ntl.nectec.or.th/thaisarn/".
- ThaiSarn Public access Network (PubNet): see "http://ntl.nectec.or.th/pubnet/".
- Public Internet Exchange (PIE): see "http://ntl.nectec.or.th/pie/".

Acronyms

BGP-4	Border Gateway Protocol version 4
CAT	The Communications Authority of Thailand
ISP	Internet Service Provider
NACSIS	The National Center for Scientific Information System
NECTEC	The National Electronics and Computer Technology Center
NTL	Network Technology Laboratory
PIE	ThaiSarn Public Internet Exchange
PIEP	Public Internet Exchange Participant
PoP	Point of Presence
QOS	Quality of Service
RADB	Routing Arbiter Database
RS	Route Server
ThaiSarn	The Thai Social/Scientific, Academic and Research Network
NIX	National Internet Exchange
TOT	The Telephone Organization of Thailand

Thaweesak Koanantakool
Director of NECTEC

Dr.Thaweesak "Hugh" Koanantakool received his Bachelor and Ph.D. degrees in Electrical Engineering from Imperial College of Science and Technology, London University. He had a number of industrial contracts in the UK before he came back to Thailand to start his government service career in 1981. He taught in Electrical Engineering with the Faculty of Engineering, Prince of Songkla University. In 1985, he moved to Bangkok Thammasat University and was appointed Associate Director of the Information processing Institute for Education and Development. Since 1994, he became Deputy Director of NECTEC as well as leading the Network/Software Technology labs. Thaweesak introduced the Internet into Thailand and set up the largest academic and research network known as ThaiSarn under NECTEC. He later co-founded the first Internet Service Provider (ISP) owned by Thai government in 1995. The ISP, Internet Thailand Company Limited, at present is the largest ISP in Thailand, has 45% market share (by IP numbers managed).
In 1996-1997, Thaweesak led Thailand's Information Superhighway test bed Project funded by NECTEC. The project was a major test bed in Thailand using ATM switches for both local area and wide-areas. In August 1998, Thaweesak was appointed the Director of NECTEC.

Chalermpol Charnsripinyo
Researcher

Chalermpol Charnsripinyo received his BS in Computer Science from Thammasat University, Bangkok, in March 1992. He started his work at Network Technology Laboratory (NTL), NECTEC, as a Research Assistant in May 1992. His main responsibility was the development of ThaiSarn network that was being set up at the time. He had worked at NTL for almost four years before he got the Royal Thai Government Scholarship to continue graduate study in Jan 1996. He is currently pursuing his Ph.D. in Telecommunication program in the US. His areas of interests concentrate on high-speed networking, ATM networking, Internet technologies, Network Performance and Analysis, Network Management, Parallel and Distributed System, and Real-time systems.

Angkana Angkalukkana
Research Assistant

Angkana Angkalukkana was born in Bangkok, Thailand on 21 April 1976. She received her BS in Computer Science from Thammasat University in

1997. She joined the Network Technology Laboratory, NECTEC since May 1997. She was initially responsible for network engineering in ThaiSarn and PubNet. Her current responsibilities include maintaining, designing and developing network for ThaiSarn, SchoolNet, PIE, and PubNet. Her interests are Internet Routing Architectures, ATM Technology, Network Security and Internet Technologies.

Pornthep Narula
Research Assistant

Pornthep Narula, a.k.a. Tep, joined NTL right after receiving his B.Eng. (Computer) from the KMITL, Bangkok, back in May 1994. His roles at NTL range from system engineering to system and network design and capacity planning. Between August 1997 and January 1998, he was sent to be a Visiting Researcher at the Telecommunication Researcher Laboratories (TRLabs), Winnipeg, Canada, to conduct research in the area of Distributed Computing. Presently, Tep has been assigned to look after the Public Internet Exchange (PIE) and technical aspects of the Kanchanapisek Network (KPNet). He is also leading the R&D efforts of GITS, providing advisory to the SchoolNet@1509 and PubNet projects, and taking part in NTL's Public-Key Infrastructure Task-Force (PKITF). Tep's personal interest nowadays centers around open distributed computing infrastructure, information security and privacy, and Internet as the universal information infrastructure. Specific topics of interest include smart card, embedded systems, and PKI.