



UNIVERSITI PUTRA MALAYSIA

**PROTECTION SCHEMES FOR FIBER –TO-THE-HOME ACCESS
NETWORKS WITH INTRA NETWORK SWITCH**

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**PROTECTION SCHEMES FOR FIBER-TO-THE-HOME
ACCESS NETWORKS WITH INTRA NETWORK SWITCH**

By

P'NG WON TIANG

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirement for the Degree of Doctor of Philosophy**

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To My Parents



Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

**PROTECTION SCHEMES FOR FIBER-TO-THE-HOME
ACCESS NETWORKS WITH INTRA NETWORK SWITCH**

By

P'NG WON TIANG

November 2007

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Faculty : Engineering

Today, data traffic is increasing at an unprecedented rate and has pushed the existing network infrastructure to the limit particularly in the access layer. There has been many development of high speed protocols to meet the demands but the existing physical medium, which consists of copper-based network, do not have the capabilities to support these protocols. This is the reason why the problem of access network bottleneck still exists and has severely hinders the ability of service providers to offer new high-speed data services to their customer.

Telephone companies are now working enthusiastically to switch from copper to fiber based network: Fiber-To-The-Home (FTTH); one that is inexpensive, simple, scalable, and capable of delivering bundled voice, data and video services to an end-user over a single network. However, there is still one obstacle, which has been generally overlooked, which is, providing protection to the access line. The fiber optics access mainly consists of a single fiber running upstream and a single fiber running downstream. If a protection path were to be created, the network provider would have to lay another 2 fibers on the network. This would increase deployment costs and also costs

for the subscribers. Thus, a new way of providing fault tolerance to the system has to be introduced, by taking costs consideration and also efficiency in deploying the solution.

In this thesis, three novel cost efficient schemes for providing fault tolerance to the FTTH system are introduced and methodologies to detect failures are also suggested. In ‘Asynchronous Transfer Mode Passive Optical Network (APON) FTTH access network with an intra network switch’ scheme, various classes of traffic, which logically represent different applications based on their Quality of Service (QoS) requirements, are defined. Access packets are switched to available working Optical Line Terminals (OLTs) according to prioritization in time of failure. In ‘Time Slots Switching (TSS)’ protection scheme, a new algorithm is proposed to cut off the empty portion of a time slot and the proposed switch will arrange time slots from all Optical Network Units, ONUs, (including ONU originally served by the faulty OLT) to be sent to working OLTs in round robin fashion. In ‘Time Slots Redistribution (TSR)’ protection scheme, protection is provided through redistribution of time slot allocated to ONUs by OLT to accommodate the ONUs of the failed OLT.

The survival of the network is studied by terminating the supporting OLT unit one after another in simulation and observing the packet delay, packet loss ratio, the buffer occupancy and also the throughput of the switch. Results show that for different traffic classes, the number of supportable ONUs exceeds the standard value of the Full Service Access Network (FSAN) recommendations, which are 32 units per OLT. Cost analysis also shows proposed protection schemes are more cost efficient than all existing protection schemes. These results highlight the contribution of this thesis.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SKIM-SKIM PERLINDUNGAN BAGI JARINGAN AKSES GENTIAN-OPTIK-KE-RUMAH MENGGUNAKAN SUIS PERANTARAAN JARINGAN DALAMAN

Oleh

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Pada masa kini, peningkatan trafik data dalam kadar yang menakjubkan telah mengguna infrastruktur rangkaian jaringan akses secara maksimanya. Pembangunan protokol berhalaju tinggi yang telah dilakukan bagi menampung kehendak ini pula dihad oleh media fizikalnya, jaringan berasaskan dawai. Ini merupakan sebab masalah akses masih wujud dan telah mengehad kemampuan penawar perkhidmatan untuk menawarkan perkhidmatan data berhalaju tinggi kepada pelanggan.

Syarikat-syarikat telefon dewasa ini berusaha menukar jaringan berasas dawai kepada jaringan berasas gentian optik: gentian-optik-ke rumah (FTTH) yang murah, mudah, boleh dilanjutkan dan berupaya mneyampaikan perkhidmatan suara, data dan video kepada pengguna melalui satu jaringan sahaja. Namun, terdapat satu halangan yang sering terabai perlu diatasi iaitu memberi perlindungan kepada jaringan capaian. Jaringan capaian merangkumi satu saluran gentian optik yang membawa maklumat ke hulu jaringan dan satu lagi gentian optik yang membawa maklumat ke hilir jaringan. Jika penawar perkhidmatan ingin mengadakan perlindungan bagi saluran rangkaian gentian optik, 2 lagi gentian optik tambahan perlu diletakkan ke dalam rangkaian tersebut. Ini akan meningkatkan kos pemasangan dan juga kos untuk menggunakan perkhidmatan

tersebut. Oleh itu, satu cara baru untuk memberi perlindungan kepada rangkaian akses tersebut perlu diperkenalkan dengan memberi penekanan kepada kos dan kecekapan kaedah tersebut.

Di dalam tesis ini, tiga skim baru yang berkos rendah untuk menawarkan perlindungan kepada sistem FTTH telah diperkenalkan dan kaedah untuk mengesan kerosakan juga dicadangkan. Kaedah ‘Jaringan akses APON FTTH dengan satu suis perantaraan jaringan’, pelbagai jenis kelas trafik yang mewakili pelbagai jenis aplikasi bergantung kepada kualiti perkhidmatan (QoS) mereka telah diperkenalkan. Paket yang membuat akses akan disalur ke OLTs yang berfungsi mengikut keutamaan masa kegagalan mereka. Dalam kaedah perlindungan ‘Pensuisan Selit Masa (TSS)’, satu algoritma baru untuk memotong bahagian selit masa yang kosong dan suis yang diperkenalkan akan mengatur selit masa daripada semua ONU (termasuk ONU yang asalnya diservis OLT yang rosak) kepada OLT yang berfungsi secara bergilir. Dalam kaedah perlindungan ‘Pengagihan Semula Selit Masa (TSR)’, perlindungan diberi melalui pembahagian semula selit masa yang diberi kepada ONU oleh OLT bagi menawarkan perkhidmatan kepada ONU yang diservis OLT yang rosak.

Keupayaan tahanan rangkaian tersebut dianalisis dengan mensimulasikan kerosakan OLT-OLT dalam rangkaian tersebut. Parameter-parameter seperti kelengahan paket, nisbah kerosakan paket, bilangan paket yang menduduki penimbal suis yang digunakan dan juga truput suis tersebut. Dalam keputusan simulasi yang didapati, bilangan ONU yang dapat disokong oleh rangkaian tersebut adalah melebihi bilangan ONU yang direkomendasikan oleh FSAN, iaitu hanya 32 unit untuk satu OLT. Analisis kos juga menunjukkan skim-skim perlindungan yang dicadang adalah lebih kos efektif daripada semua skim perlindungan yang sedia ada. Keputusan-keputusan ini menonjolkan sumbangan tesis ini.

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I certify that an Examination Committee has met on 15th April 2008 to conduct the final examination of P'ng Won Tiang on his Doctor of Philosophy thesis entitled "Protection Schemes for Fiber-To-The-Home Access Networks with Intra Network Switch" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or currently and is not concurrently submitted for any other degree at Universiti Putra Malaysia or other institution.

P'NG WON TIANG

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LIST OF ABBREVIATIONS

AAL	ATM Adaptation Layer
ADM	Add / Drop Multiplexers
ADSL	Asymmetric Digital Subscriber Line
APON	Asynchronous Transfer Mode Passive Optical Network
ATM	Asynchronous Transfer Mode
BPON	Broadband Passive Optical Network
CDMA	Code Division Multiple Access
CM	Cable Modem
CSMA/CD	Carrier Sense Multiple Access With Collision Detection
CO	Central Office
DBA	Dynamic Bandwidth Allocation
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
EFM	Ethernet in the First Mile
EPON	Ethernet Passive Optical Network
FDMA	Frequency Division Multiple Access
FSAN	Full Service Access Network
FTTH	Fiber To The Home
GPON	Gigabit Passive Optical Network
HFC	Hybrid Fiber Coaxial
IEEE	Institute of Electrical and Electronics Engineers

IFG	Inter-Frame Gap
IP	Internet Protocol
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
LAN	Local Area Network
LW	Loss Weight
MAC	Media Access Control
MTU	Maximum Transmission Unit
OLT	Optical Line Terminal
ONT	Optical Network Terminal
ONU	Optical Network Unit
ORU	Optical Repeater Units
OSP	Outside Plant
RF	Radio Frequency
PLOAM	Physical Layer Operation, Administration, And Maintenance
PON	Passive Optical Network
SCMA	Subcarrier Multiple Access
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
SPON	Super Passive Optical Network
TDM	Time Division Multiplexing
TH	Threshold