Network Management Solution for PS/PON, WDM/PON and Hybrid PS/WDM/PON using DS-OCDM

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Abstract: A no el network management solution or PS PON WDM PON and PS WDM PON is proposed and de eloped. Modi ied DS OCDM o ercomes OTDR s ortcomings and capacity limitation o known PON management tec niques or standard and ad anced PON arc itectures.

OCIS codes: (. 33 Fi er optics communications; (.45 Optical communications

1. Introduction

Passi e Optical Networks (PONs seem to e t e ultimate winning solution or tomorrow s last irst mile ottleneck. Started rom : (i er to customer in t e early 9 s passi e splitters (PS ena led up to : 8 or t e GPON standard wit orward error correction (FEC . PON managers owe er still lack e icient monitoring tec nology appropriate or PS ased PON and its deri ati es[ ].

In t is paper we ocus on some o t e In Ser ice management pro lems and propose or t e irst time to our knowledge a simple optical code di ision multiplexing (OCDM ased arc itectural sc eme t at o ercomes not only t e PS PON pro lems ut are also applica le to more ad anced PON arc itectures like wa elengt di ision multiplexing WDM PON and y rid PS WDM PON (w ere a PS PON like system is uilt o er e ery wa elengt in a passi e WDM network . Note t at in our application we use t e OCDM codes to carry management in ormation and not t e data itsel . T is makes t e proposed OCDM sc eme easy to implement as low transmission rates su ice.

2. An OCDM solution for In-Service PS/PON Management

Standard OTDR ased on Rayleig ackscattering and power re lections used to monitor point to point links are ine ecti e in PS PONs [4]. Eac ranc termination connected to an optical network unit (ONU as well as e ery splice connector and i er de ault or reak contri utes to a re lection peak and or power loss step. I two equidistant ranc es experience ailure t ey are indistinguis a le. E en w en a i er ault results in a clear e ent t e aulty ranc is not identi ied requiring a track roll tour and outside inter ention o tec nicians. E ery ranc must e c ecked separately rom its end y means o upstream OTDR transmission in order to identi y t e aulty one [ ].

Few solutions or In Ser ice PS PON management a e een proposed [3]; all o t em impractical. For instance a unique signature (or identi ier may e assigned to eac leg o t e network e ore t e ONU. A discrete Bragg grating wit a unique wa elengt is placed at eac ONU. At t e CO side di erent interrogation tec niques a e een proposed including a road and source multi wa elengt laser and tuna le laser and ilters etc. [4]. T ese systems are impractical or ig num ers o su scri ers due to t e ery large spectrum to e sliced *i e* one slice or e ery network leg. For 3 ome customers (respecti ely 8 in GPON wit FEC and using narrow slice widt o .8 nm a total andwidt o 5. nm (respecti ely .4 nm is required [3].

Our OCDM management tec nique requires only one wa elengt pre era ly in t e 5 nm already reser ed or standard FTTH PS PON monitoring. Our tec nique is also scala le or more ad anced and complex PON networks always using only a single wa elengt . As illustrated in Fig. e ery network leg is terminated y a standard passi e wa elengt selector (WS widely used in PONs isolating t e standard monitoring U and rom t e ot er data ands at t e ront o e ery ONU and at t e CO as well.

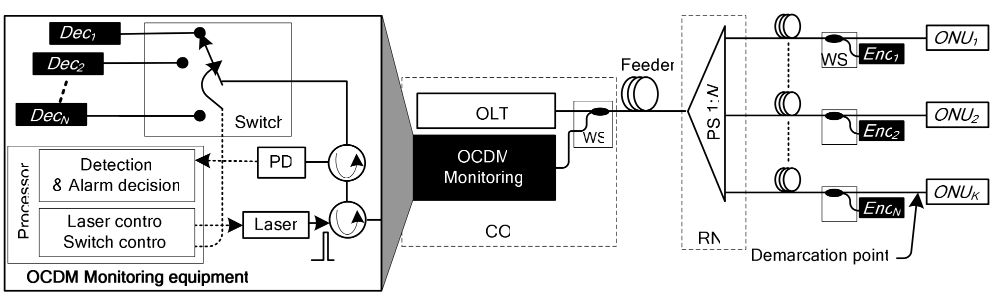

Fig. 1. OCDM ased PS PON monitoring system e ery network leg is assigned an encoder one tunea le decoder at t e CO.

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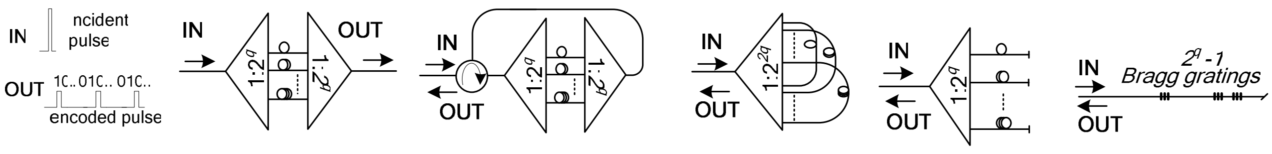

Components	PSs o : q	PSs o : q circulator	PS o : q	PS o : q	multiple FBG
Loss in dB	3 q	3 q	3(q	q α	7 to
	(a	(	(c	(d	(e

Fig. 2. Encoding designs: (a standard encoder (modi ied encoder (c q splitter encoder (d q splitter encoder and (e MBG encoder.

T e transmission section o t e OCDM monitoring equipment at t e CO (Fig. consists o a U and pulsed laser dri en y a processor to transmit ns (or s orter pulses wit a predetermined low requency rate (ew mega ertz or lower . E ery pulse propagates t roug t e tree network split at t e PS is coded y t e encoders re erred as Enc_i *i* to and is t en re lected ack to t e CO. An encoder consists o a passi e de ice t at ragments an incoming pulse to a num er o *p* su pulses and distri utes t em in time according to a speci ic code *i e.* direct sequence coding in t e time domain. E ery encoder at t e leg termination implements a unique code. Our proposed network management system is a modi ied orm o direct sequence DS OCDM and our codes are also t e so called optical ort ogonal codes (OOC . T e PS (coupler com ines t e upstream encoded pulses toget er as in standard OCDM. In t e CO a tuna le DS decoder consisting ere o an optical switc and a ank o ixed decoders (similar to encoders ut introducing delays in re erse order discriminates responses coming rom di erent ranc es o t e tree network. E ery ealt y ranc in t e network contri utes an auto correlation peak. A missing autocorrelation peak indicates t e corresponding network leg is roken or ex i its a normal power loss.

3. Encoder design

Our DS OCDM network management tec nique is di erent rom standard DS OCDMA tec nique in arious aspects: low required transmission rate dramatically alle iating t e known implementation c allenges o OCDMA no reception no transmission or modulation at t e ONU side only t e coding operation is needed and 3 w ile standard DS encoders Fig. (a work in transmission in our case re lection is t e key encoder property.

We propose our designs o modi ied DS encoder all appropriate or our application in Fig. (to (e . All exploit splitters and delay lines to ragment t e incident pulse into su pulses disperse t em gat er t em ack to t e i er and return t em to t e CO. Eac o t ese encoder designs as its own ad antages and draw acks. T e irst Fig. (is t e straig t orward modi ication o t e standard one o Fig. (a entails x : q splitters and one circulator. T e second implementation in Fig. (c requires one : q splitter and sa es t e circulator. T e implementation in Fig. (d requires only one : q splitter and inally Fig. (e is an implementation uses a multiple Bragg grating *i e.* a series o discrete gratings at t e same wa elengt ut wit di erent re lection intensities and p ysical locations [7].

We de ine t ree key design parameters or our system: ig coding capacity (t e num er o di erent codes s ould e a minimum o 8 or standard GPON wit FEC ; t e modi ied DS encoders to e located at t e network legs s ould e low cost and low component count; and 3 t e power loss etween t e incident pulse and re lected coded signal ed ack to t e i er s ould e minimized.

T e encoder in Fig. (is t e most expensi e ecause o t e circulator (wit .5 dB loss per pass and ex i its t e ig est power loss. T e encoder in Fig. (d is less expensi e owe er ex i its ery ig loss due to t e re lection coe icient α typically a out 4 (3 dB [8]. T e encoder in Fig. (c is less expensi e t an t at in Fig. (e ecause o t e Bragg gratings compared to PSs owe er MBGs as less insertion loss.

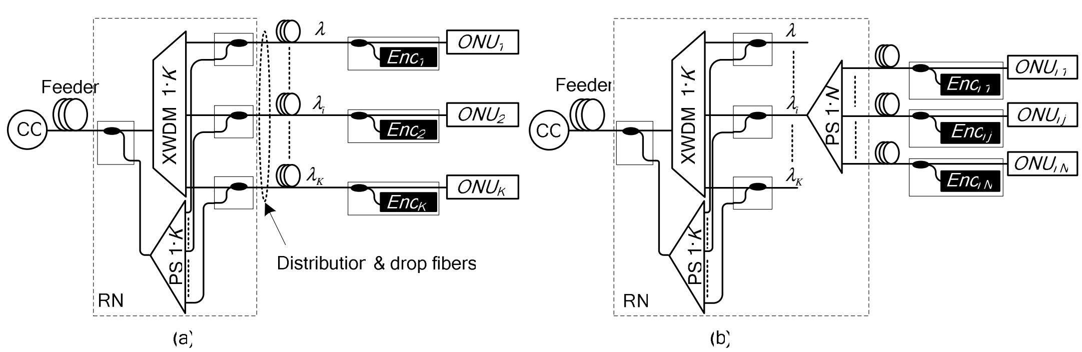

Fig. 3. Implementation o OCDM management in ad anced PONs: (a WDM PON and (PS WDM PON.

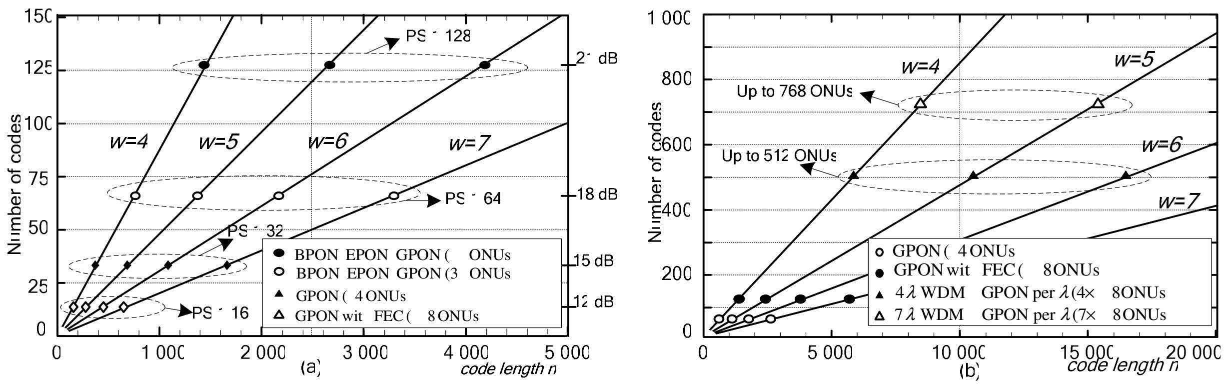

Fig. 4. Coding system design tool: (a PS PON systems (PS WDM PON systems.

4. Applicability to WDM/PON and PS/WDM/PON

In Fig. 3 we de elop an arc itectural solution t at allows our tec nique to manage more ad anced and complex PON arc itectures. In WDM PON e ery customer is ser ed y dedicated wa elengt [5]. Pre iously proposed PON management uses al o wa elengt s or data and t e ot er al or monitoring. E ery customer is dedicated two wa elengt s one or data and anot er or monitoring. A wa elengt selector is place e ore t e WDM demultiplexer in order to separate t e monitoring and at t e 5 nm. Upstream and downstream data is assumed ere to s are t e same i er; ot er ariants could e similarly deri ed. Our tec nique sa es all t e monitoring wa elengt s and makes t em a aila le or data ence dou ling t e network capacity. Only a single monitoring wa elengt is split and distri uted to all clients.

5. Coding system design

Let Ω e a collection o inary *n* tuplets generated y [9] rom t e speci ication (n λ_a λ_c w ere *n* is t e code lengt is t e Hamming weig t λ_a and λ_c are used as ollows. For ectors X $Y \in \Omega$ t e expressions $R_X(\tau)=\sum_{i=}^{n} X(i)X(i+\tau) \le \lambda_a$ and $R_{XY}(\tau)=\sum_{i=}^{n} X(i)Y(i+\tau) \le \lambda_c$ de ine respecti ely t e autocorrelation and t e cross correlation unctions ot or $-n+ \le \tau \le n-$. Note t at t e code weig t (*i e* t e num er o ones per code is equal to t e num er o delay lines in t e encoding de ices o Fig. (to (d and t e num er o Bragg gratings in t e MBG encoder o Fig. (e .

In [9] t e aut ors recently de eloped an OOC generating tec nique so called Outer product matrix ased algorit m t at maximizes t e num er o codes or gi en weig t and lengt *n* and unit cross correlation and auto correlation side lo es (λ_a=λ_c= . We used t is algorit m to de elop a coding system. In Fig. 4(a and 4(we s ow t e num er o codes (i.e. clients *s* code lengt *n* or di erent code weig ts . From Fig. 4(a a designer could determine t e appropriate (*n* pairs to support EPON GPON etc. For =4 our delay lines are required t e encoder o Fig. (c uses one :8 PS (*i e.* : ^{3} PS wit *q*= and t e MBG encoder o Fig. (e entails our gratings. Fig. 4 (presents codes t at could support PS WDM PON o Fig. 3(.

6. Conclusion

We proposed a no el PON management solution using modi ied DS OCDM system t at o ercomes t e OTDR s ortcomings or point to multipoint networks and t e capacity limitation o pre iously proposed monitoring tec niques. Our solution easily scales up rom PS PON to WDM PON and PS WDM PON supporting close to a t ousand customers all using only one monitoring wa elengt . We de eloped di erent encoding settings or our system and de eloped a design tool o appropriate codes.

8. References

[ ] Girard André FTTx PON Tec nology and Testing EXFO Electro Optical Engineering Inc. Canada 5 ISBN 5534 3.

[ ] Ye C ien Hung C i Sien Optical i er ault sur eillance or passi e optical OPTICS EXPRESS ol. 3 No. 4 July 5.

[3] P ei er *et al* "Monitoring and protecting t e optical layer in FTTH networks" in Proceedings o t e 5 FTTH Con erence 5.

[4] C an *et al.* Fi er Fault Identi ication or Branc ed Access Networks... *IEEE hotonics ech Let.* ol. no. 5 May 999.

[5] Park *et al* Optical ault monitoring met od using road and lig t source in WDM PON *Electronic Let* ol. 4 no. 4 t Fe .

[ ] Hann *et al* "Monitoring tec nique or y rid PS/WDM PON y using " Measurement *Science and echnology* 7(pp. 7 74.

[7] Castro *et al* "No el Super Structured Bragg Gratings or Optical Encryption " *J o Light a e echnology* ol. 4 no. 4 April .

[8] Derickson Denis *Fiber ptic est and easurement* Prentice Hall PTR New Jersey 7458. ISBN 3 53433 5.

[9] C armc i *et al* Outer Product Matrix representation o Optical Ort ogonal Codes *IEEE rans on Comm.* ol. 54 No. June .