ITU-T Kaleidoscope 2010
Beyond the Internet? - Innovations for Future Networks and Services

Traffic Analysis and Network Protection in Photonic Switched Optical Metro-Access Networks

Felipe Rudge Barbosa
University of Campinas – Unicamp
Rudge@dsif.fee.unicamp.br

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Innovations for future networks and services

Traffic Analysis and Network Protection in Photonic Switched Optical Metro-Access Networks

Indayara Bertoldi Martins
Felipe Rudge Barbosa *
Edson Moschim

Laboratorio de Tecnologia Fotonica – LTF
DSIF-FEEC- UNICAMP
(* Instituto Namitec – *INCT/MCT-CTI*)
BRASIL

Flight Plan

- ❑ Objectives & Introduction
- ❑ Topologies and Optical Nodes
- ❑ Basic theory
- ❑ Simulation plan
- ❑ Results & Discussion
- ❑ Conclusion

Objectives and Motivation

This work looks at:

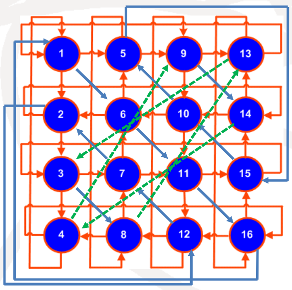
- ❑ Network Performance analysis and link failure sensitivity using Photonic Switching (OBS/OPS types), for Metro-Access networks;
- ❑ Innovative topology configurations are considered
- ❑ Analytic and Simulation approaches are realised;
- ❑ New results appear !
- ❑ And we see new technologies bringing new functionalities to the Optical Layer, more efficiently – indicating savings in network (usage) time & energy.

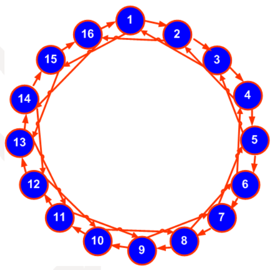
Introduction

- For core networks WDM (OCS) is definetely established;
- For Metro-Access, in order to avoid (unnecessary) O/E conversions OPS/OBS technologies are attractive solutions within WDM channels, to offer granularity and capacity, with significant reduction of network latency and energy consumption;
- Important aspects are service survivability and network protection under link failure (the most common case is a single failure at a time..);
- We look at traffic analysis and network protection in OBS/OPS networks having mesh topologies and ring topologies; the usual tree topology for access networks (EPON/GPON) is not considered because it is incompatible with asynchronous traffic assumed here;
- Performance metrics are based on network capacity, average number of hops (ANH) and packet loss fraction.

Optical Network Topology

Manhattan Street Mesh and New Ring topologies





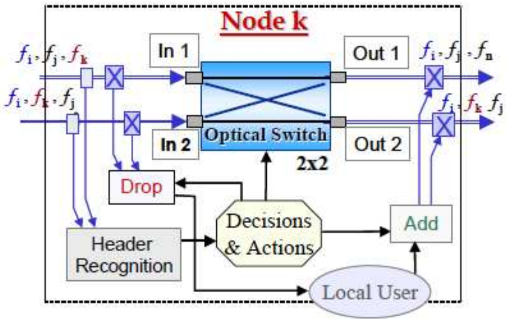
- Each node is (*PxP*), P=2,3, 4, plus add/drop ports; modified MS;
- Uni- and bidirecional links ;
- N=m^2 nodes;
- Regular when *m* even ;
- Quase-regular when *m* odd ;

- Each node is (*2x2*), plus add/drop ports;
- Uni- and bidirecional links;
- the New Ring is to be compared with the 2x2 MS network;
- connectivity is one to next (N+1) and previous (N-2) neighbours;

Optical Network Node & Packet

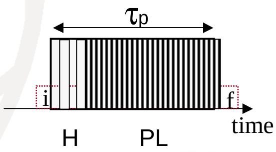
❑ Optical Node includes :

- 2, 3, 4 inputs and outputs, *plus* add/drop
- header processing
- bufferless at optical layer, but includes FDL (*fiber delay line)*



❑ Optical Packet/Burst:

- Header: final destination;
- Payload : digital content (data, video, voice)
- assynchronous operation;
- concatenation at arrival (*solvable problem*)



Routing Protocols

❑ *Store and Forward (SF)* – packets are held and sent only through the shortetst path to destination ; minimize ANH, but has an impact on delay and latency. (*instrumental in the analytic computations*).

❑ *Deflection Routing (DR)* – packets are sent to the network, without regard to path; contention is resolved by deflection to avaible port; deflections avoid packet loss, latency is minimized, but ANH always increases. (*instrumental in network traffic simulation*).

Basic Theory

- Network capacity :

$$C_t = \frac{P.N.S}{\overline{H}}$$

- Link failure alters capacity as:

$$C_t = \frac{(P.N - m).S}{\overline{H}}$$

Note: *ANH is recalculated after failure, disconsidering the missing links*

- Performance factor :

$$F_p = \frac{C_t}{\overline{H}}$$

N : # nodes ;
S : link transmission rate ;
H : ave. # hops (ANH);
m: # link failures (simult.) ;
Lc : link load ;
P : # node ports (2, 3, 4)

Results >>

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Analytic Results

Topology Mesh/ SF protocol / more and less used links

Topology		Link failure		Capacity Without	Capacity With	ΔC (-%)	Number of hops Without	Number of hops With	ΔH (+%)	Factor of performance Without	Factor of performance With	ΔF(-%)
(2x2)	MSq-9	more used	3, 1	22,34	21,18	5,22	2,014	2,125	5,51	11,09	9,97	10,17
(2x2)	MS-16	more used	4, 1	27,28	26,52	2,78	2,93	3,017	2,86	9,30	8,79	5,49
(2x2)	MSq-25	more used	2, 3	38,11	37,35	2,00	3,28	3,347	2,04	11,62	11,16	3,96
(2x2)	MS-36	more used	2, 3	48,47	47,61	1,77	3,71	3,781	1,80	13,05	12,59	3,51
(2x2)	MSq-9	less used	8, 5	22,34	20,90	6,46	2,01	2,153	6,90	11,09	9,71	12,50
(2x2)	MS-16	less used	13, 16	27,28	26,52	2,78	2,93	3,017	2,86	9,30	8,79	5,49
(2x2)	MSq-25	less used	25, 21	38,11	37,43	1,80	3,28	3,34	1,83	11,62	11,21	3,56
(2x2)	MS-36	less used	26, 27	48,47	47,61	1,77	3,71	3,781	1,80	13,05	12,59	3,51
(3x3)	MSq-9	more used	1, 2	40,91	38,46	5,98	1,65	1,69	2,42	24,79	22,76	8,21
(3x3)	MS-16	more used	2, 3	56,07	54,40	2,99	2,14	2,16	0,93	26,20	25,18	3,89
(3x3)	MSq-25	more used	4, 5	73,82	72,27	2,10	2,54	2,56	0,79	29,06	28,23	2,87
(3x3)	MS-36	more used	6, 1	92,15	90,68	1,60	2,93	2,95	0,68	31,45	30,74	2,26
(3x3)	MSq-9	less used	9, 7	40,91	38,46	5,98	1,65	1,69	2,42	24,79	22,76	8,21
(3x3)	MS-16	less used	13, 16	56,07	54,40	2,99	2,14	2,16	0,93	26,20	25,18	3,89
(3x3)	MSq-25	less used	21, 22	73,82	72,27	2,10	2,54	2,56	0,79	29,06	28,23	2,87
(3x3)	MS-36	less used	32, 31	92,15	90,68	1,60	2,93	2,95	0,68	31,45	30,74	2,26
(4x4)	MSq-9	more used	2, 1	60,00	59,45	0,92	1,50	1,514	0,93	40,00	39,26	1,84
(4x4)	MS-16	more used	1, 2	75,12	74,70	0,56	2,13	2,142	0,56	35,27	34,87	1,12
(4x4)	MSq-25	more used	1, 2	100,00	99,72	0,28	2,50	2,507	0,28	40,00	39,78	0,56
(4x4)	MS-36	more used	1, 2	116,88	116,47	0,36	3,08	3,091	0,36	37,95	37,68	0,71
(4x4)	MSq-9	less used	9, 8	60,00	59,45	0,92	1,50	1,514	0,93	40,00	39,26	1,84
(4x4)	MS-16	less used	16, 15	75,12	74,70	0,56	2,13	2,142	0,56	35,27	34,87	1,12
(4x4)	MSq-25	less used	25, 24	100,00	99,72	0,28	2,50	2,507	0,28	40,00	39,78	0,56
(4x4)	MS-36	less used	36, 35	116,88	116,47	0,36	3,08	3,091	0,36	37,95	37,68	0,71

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Analytic Results

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- Topology Ring / SF protocol / more and less used links

Topology		Link failure		Capacity Without	Capacity With	ΔC (-%)	Number of hops Without	Number of hops With	ΔH (+%)	Factor of performance Without	Factor of performance With	ΔF(-%)
unid	Ring-9	+ used	2, 3	20	17,89	10,53	2,25	2,375	5,56	8,89	7,53	15,24
unid	Ring-16	+ used	3, 1	24,02	22,28	7,27	3,33	3,479	4,47	7,21	6,40	11,25
unid	Ring-25	+ used	3, 1	25,88	24,57	5,07	4,83	4,986	3,23	5,36	4,93	8,04
unid	Ring-9	-used	7, 8	20	17,00	15,00	2,25	2,5	11,11	8,89	6,80	23,50
unid	Ring-16	-used	15, 16	24,02	21,89	8,87	3,33	3,54	6,31	7,21	6,18	14,28
unid	Ring-25	-used	23, 24	25,88	23,93	7,55	4,83	5,12	6,00	5,36	4,67	12,79
bid	Ring-9	+ used	same	18	14,66	18,58	2,5	2,9	16,00	7,2	5,05	29,81
bid	Ring-16	+ used	2, 3	18,78	15,63	16,80	4,26	4,96	16,43	4,41	3,15	28,54
bid	Ring-25	+ used	same	19,23	16,16	15,96	6,5	7,58	16,62	2,96	2,13	27,94
bid	Ring-9	-used	same	18	14,55	19,14	2,5	2,92	16,80	7,2	4,98	30,77
bid	Ring-16	-used	15, 14	18,78	15,63	16,80	4,26	4,96	16,43	4,41	3,15	28,54
bid	Ring-25	-used	same	19,23	16,16	15,96	6,5	7,58	16,62	2,96	2,13	27,94

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Traffic Simulation plan

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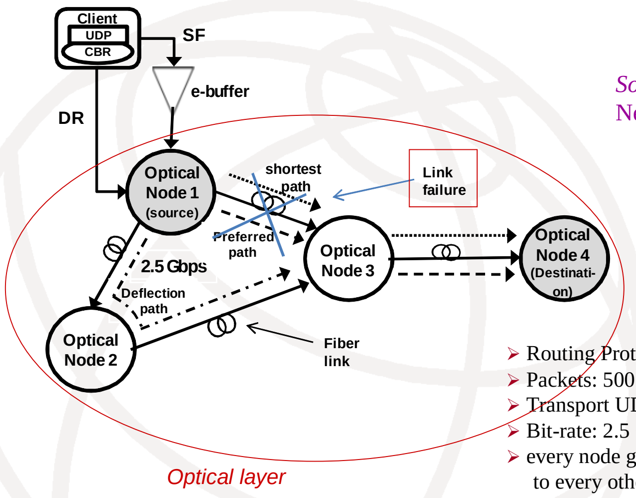


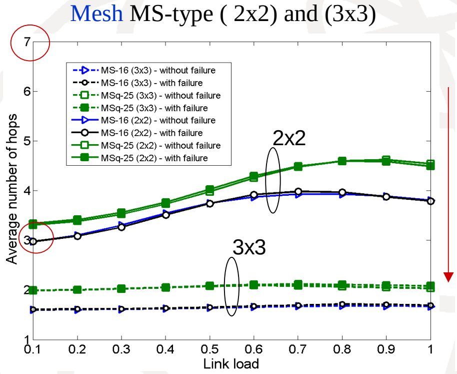
Software:
Network Simulator 2 (NS-2)

- Routing Protocol Deflection Routing (DR);
- Packets: 500 bytes (2µs);
- Transport UDP / const. Bit-rate CBR;
- Bit-rate: 2.5 Gb/s;
- every node generates uniform traffic to every other node;
- Packets per round: 2 x 10^5 (200000) ;
- Uni- and bidirecional link connections

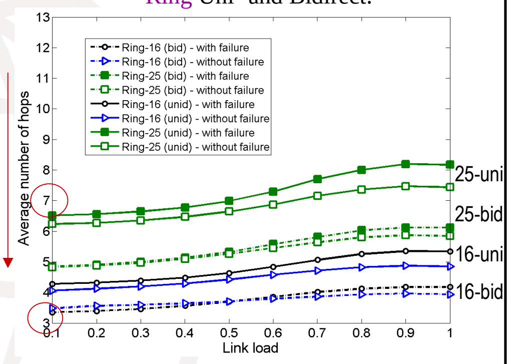
Traffic Simulation Results

Average N Hops for MS(2x2) ; MS(3x3); and Ring Uni- and Bidirect.;
with and without single link failure

Mesh MS-type (2x2) and (3x3)



Ring Uni- and Bidirect.

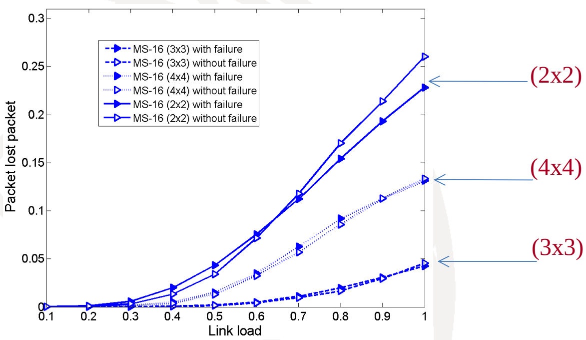


Partial Conclusions:

- ANH for mesh is always smaller than for equivalent ring;
- Mesh is more robust, “insensitive” to single failure;
- Mesh unidirect. is better,… Ring bidir. is better

Traffic Simulation Results

Packet loss fraction (PLF) for Mesh MS-16 (PxP) 2, 3, 4 ;
with/without link failure



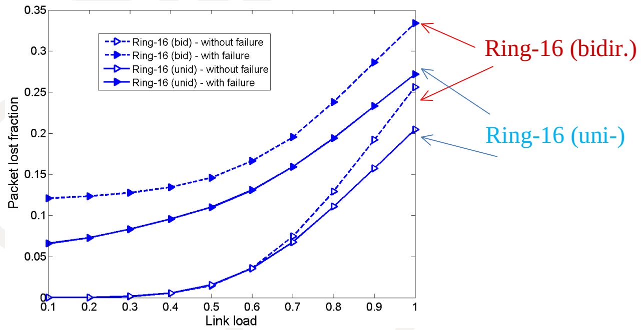
Mesh MS-16 (PxP) 2, 3, 4 ;

Partial Conclusions:

- PLF is smallest for 3x3 due to largest number of different connections;
- mesh with higher PxP is more robust, and less sensitive to single failure;
- but 2x2 is cheaper …

Traffic Simulation Results

Packet loss fraction (PLF) for Ring-16 (uni- and bidirect.) ; with/without link failure



Ring-16 (uni-) and (bidir)

Partial Conclusions:

- PLF is better for Uni- due to larger number of different connections;
- Ring is always sensitive to link failure;
- Uni- and bidir. have similar installation costs …

Conclusion

❖ Simulation and modelling are excellent tools to experiment with in network planning and evaluation;

❖ Innovative variations of mesh and ring with various interconnections of optical nodes in OPS/OBS networks offer better performance and robustness (protection to data traffic), without necessarily impacting on installation costs ;

❖ it is observed that optical nodes that have a larger number of different connections (*PxP* optical ports) to other nodes demonstrate improved performance; and should be used in more congested locations.

❖ Last – but not least! – optimized Mesh networks once again demonstrate higher performance and robustness than Ring (and tree)…
❖ details of installation and operation must be further discussed for actual installations (preferred Metro-Access level) !!

Thanks to *sponsors* and *public*

Obrigado !

☺ *Thanks for coming !!* ☺

http://www.cti.gov.br/english/

ibertold@dsif.fee.unicamp.br
rudge@dsif.fee.unicamp.br
moschim@dsif.fee.unicamp.br

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