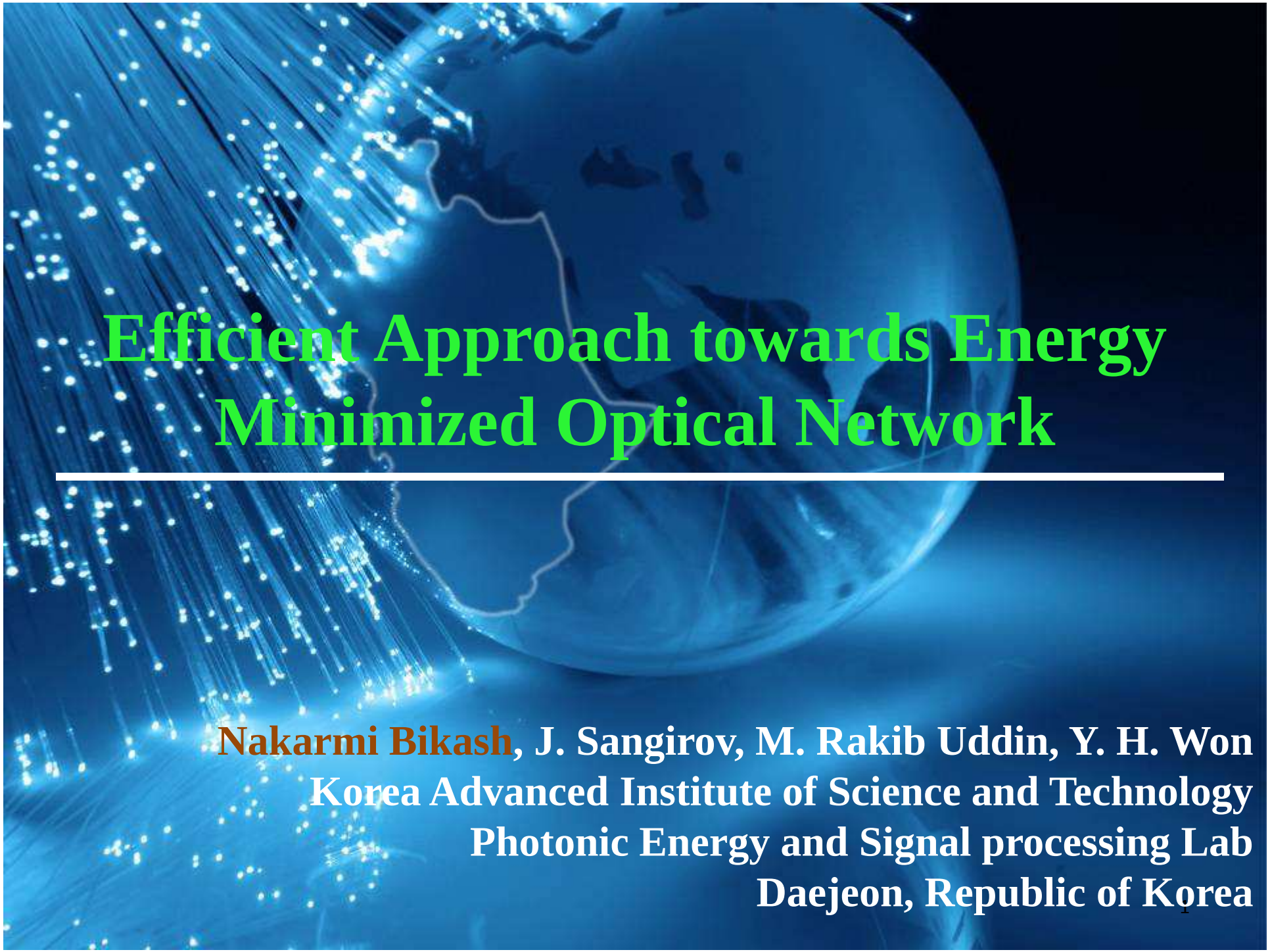

Efficient Approach towards Energy Minimized Optical Network

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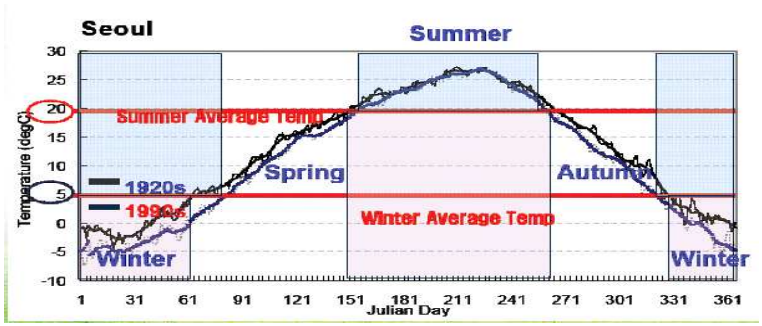
Outline

- Introduction Needs, Scenario & Approaches
- Our Focus
- Targets & Achievement
- Further Improvement
- Conclusion

Introduction: why growing issue of energy consumption

❑ Growing Issues on Environment : Simultaneous threat against the global environment and resources

- Threat against the existence of human race due to weather disasters and ecological destruction
- Economic loss predicated if energy mass consumption system continues: 5~20% of annual world GDP('06, Stern Review)
- Shortage of energy resources and increase in price
- Caused by economic development of new developing countries and continuous growth in world population



Summer Period
: Jun.3~sep.21(1920s)
-> May 24~Sep.27(1990s)
: 16days increase

Winter Period
: Nov. 21 ~ Mar. 18(1920s)
->Nov. 29~ Mar. 8 (1990s)
: 19 days decrease

Source: METRI Korea , 2006

Introduction: Scenario in optical n/w & approaches

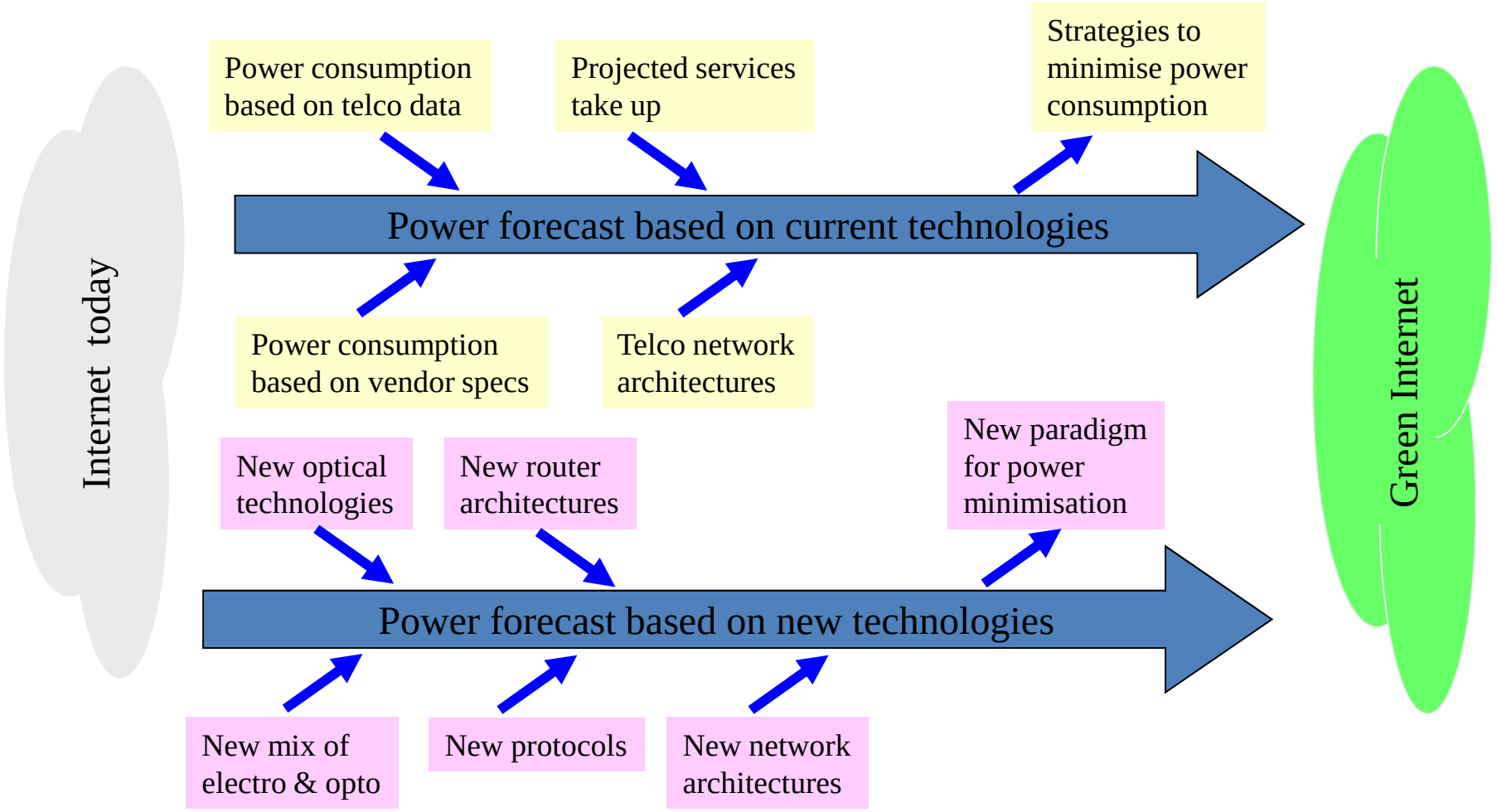
- In past no any concern with the power consumption on the optical network

- Power issue is also being taken as a resource and more focus drawn towards its efficient use

- Energy Saving Optical Technologies Tendency
  - •All-optical technology as the solution of electronic bottleneck.
  - • Current trends of developing the electronics devices: compact size higher speed
  - • As concerned more about power and development of electronics high speed devices the trends moves to the hybrid

- Finding the ways to improve power efficient networks
  - • Component level design (Improve electronic technology for the hybrid system)
  - • Power aware protocol design (low energy states)
  - • Power aware network design (New architecture i.e. bypassing)

Multi-disciplinary approach Tendency towards Future Green Internet

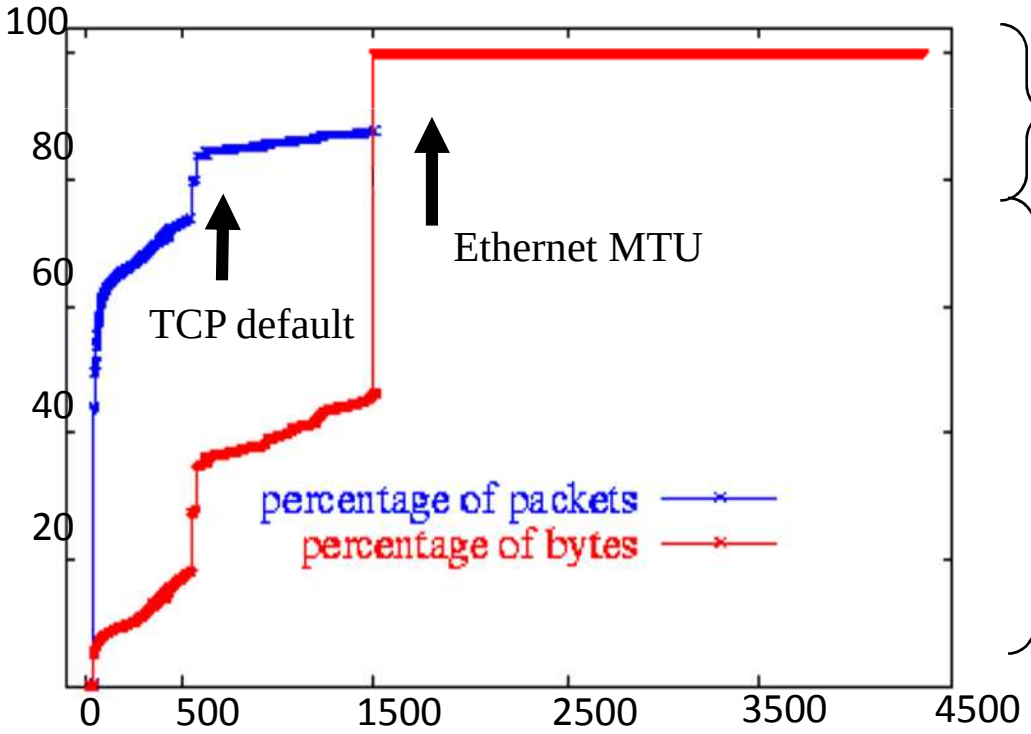


source: MERIT, Australia

Reasons for moving to Hybrid Technology:

- Current trends of developing the electronics devices: compact size higher speed
- Not necessarily introduce system benefits on the all optical systems due to transparency

Power Aware Protocol Designing

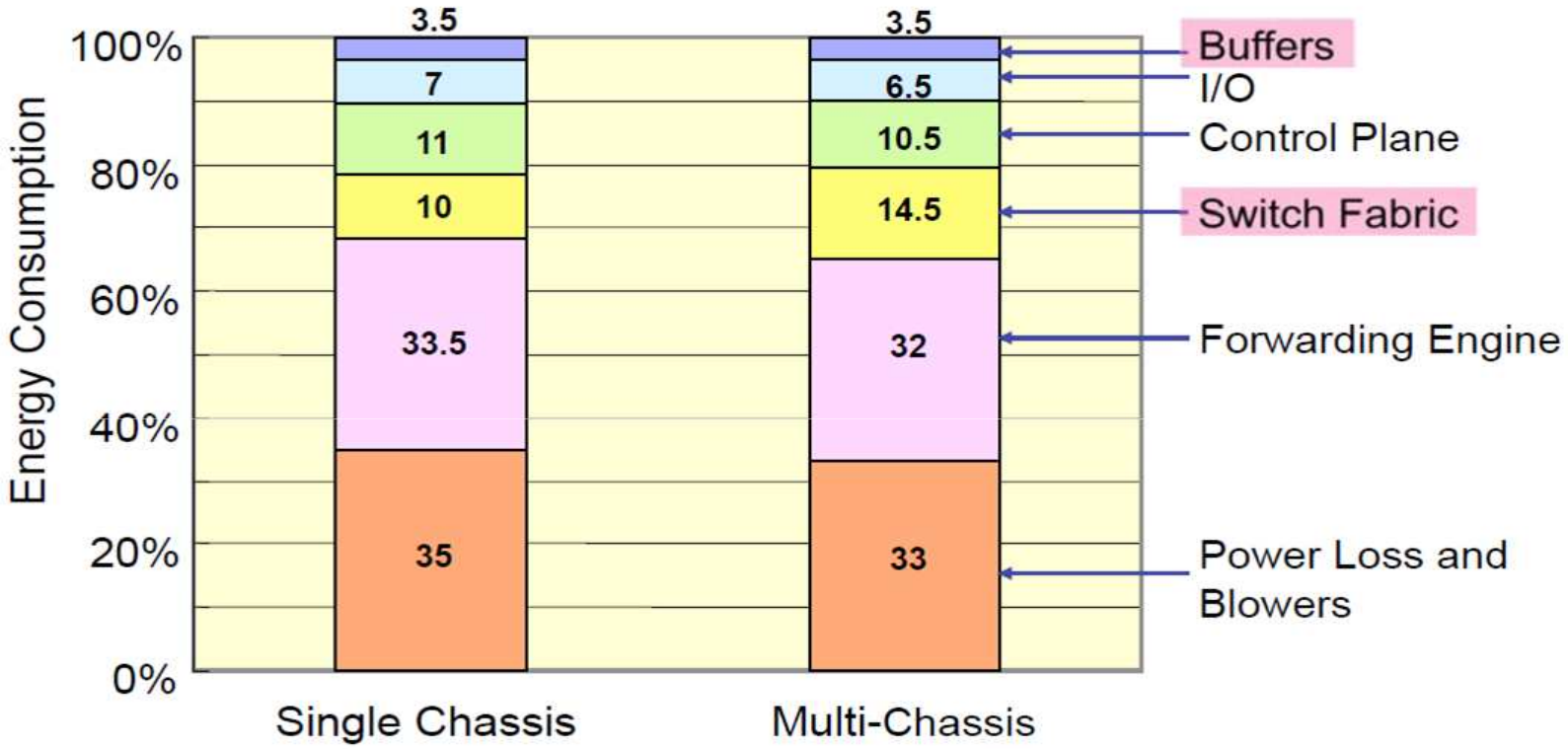


Nearly 70% by BW.
Allow generic long packets

Nearly 70% of switching times
Switching by flow bursts
AREA o research

source: Thompson, Miller, Wilder 1997

Dominance of Access Network in IP Related Processing

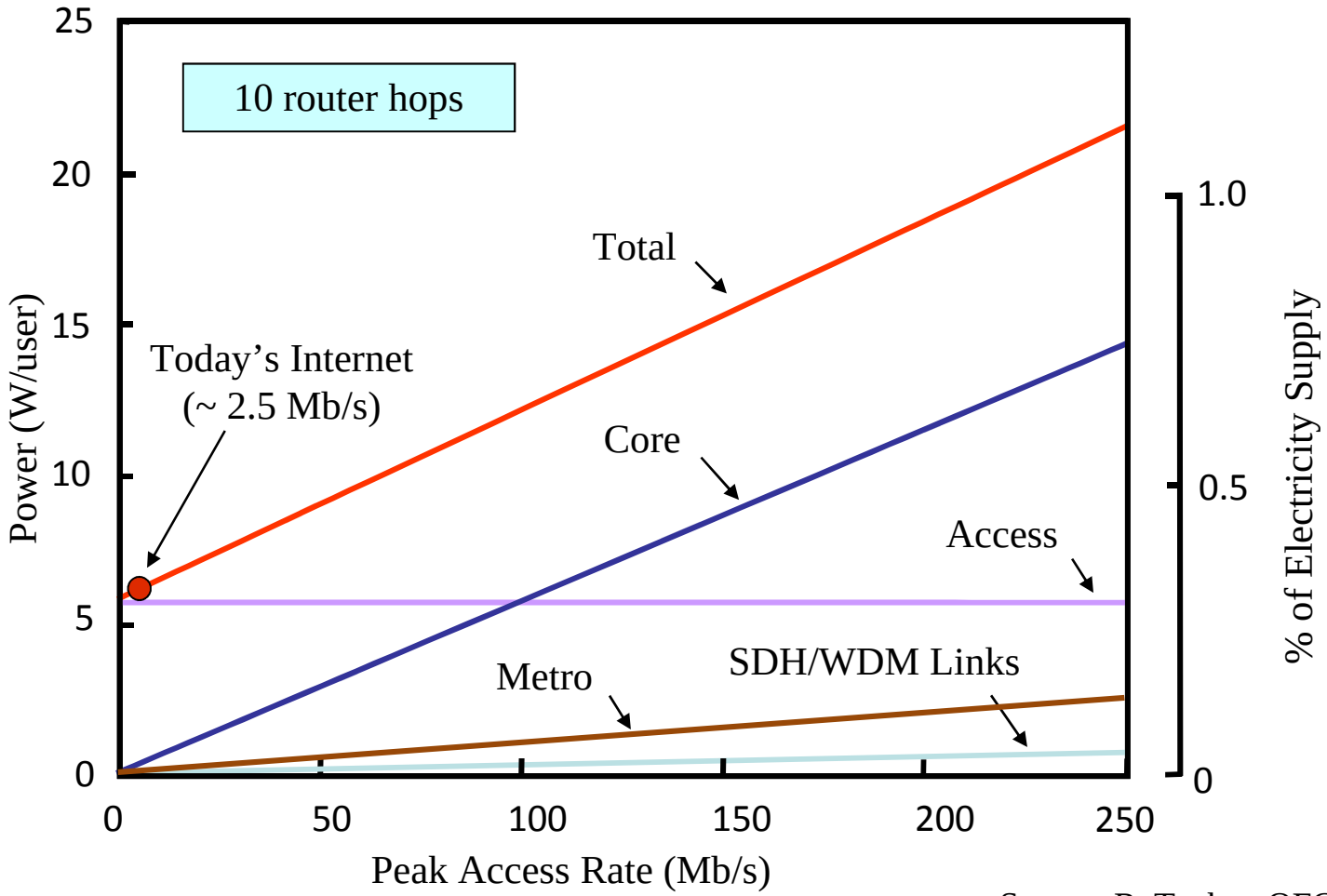


: Optical packet technology may reduce energy consumption

Source: R. Tucker, OFC 2007, photonics in Switching, San francisco, 2007

: Routing & packet protocol engineering may reduce energy consumption.

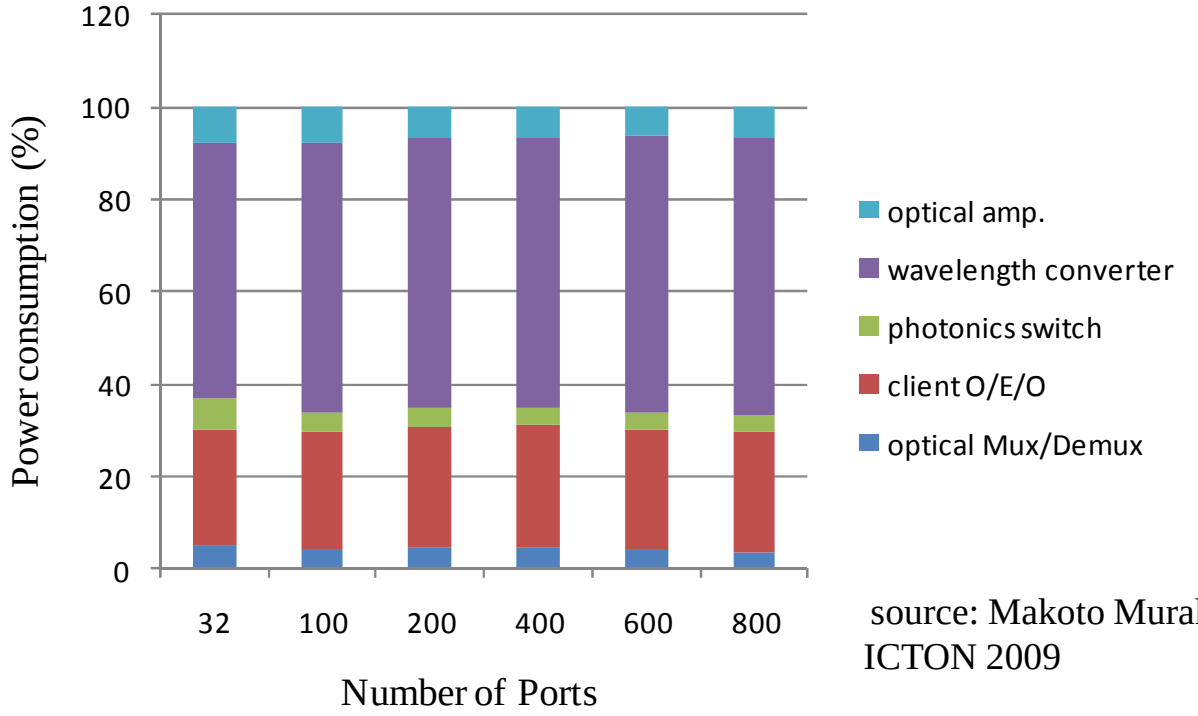
Present scenario of Power Consumption in Optical Network



Source: R. Tucker, OFC 2007

Our Focus: Present Scenario

- Still need of the OEO wavelength converter in our proposed hybrid PSMB



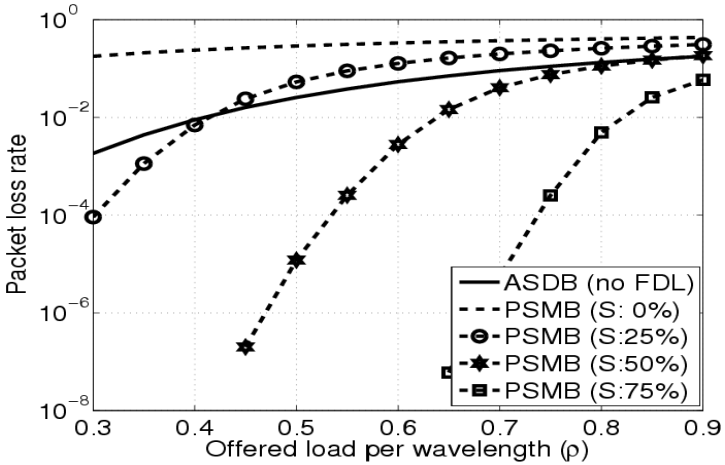
source: Makoto Murakami and Kazuhiro Oda ICTON 2009

Power consumption by various components in optical network

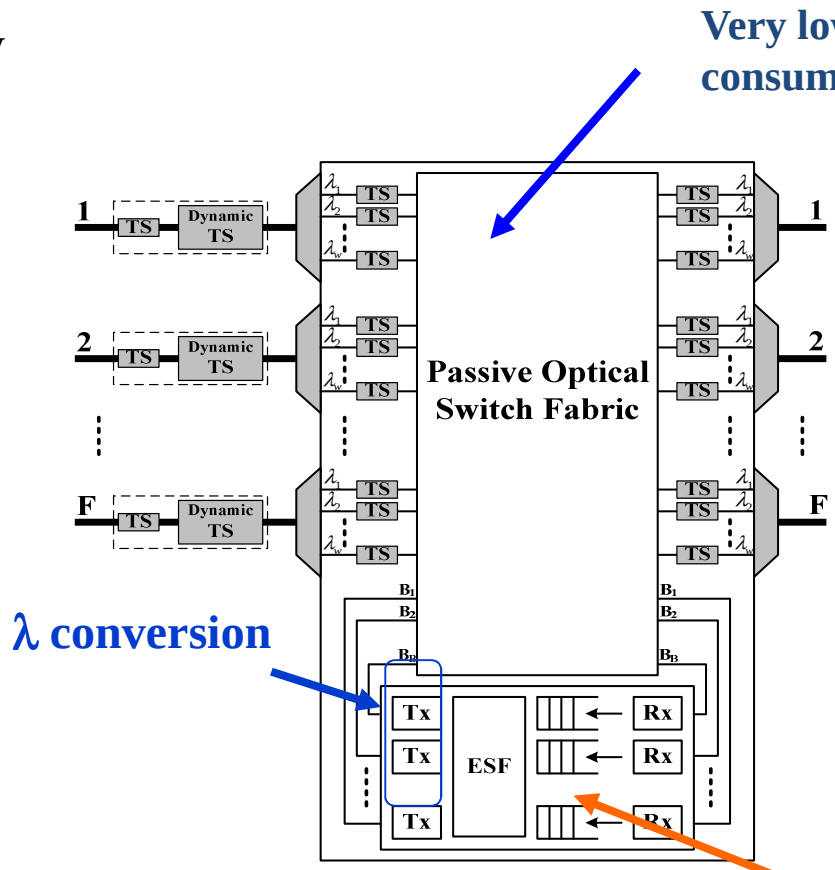
- So further approach should be taken on the minimizing of wavelength converter

Set-UP : Modification from the Past System PSMB

- On approach to the hybrid technology we used the shared electronics buffer
- Change all optical wavelength converter to the OEO wavelength converter
- Change the Node architecture



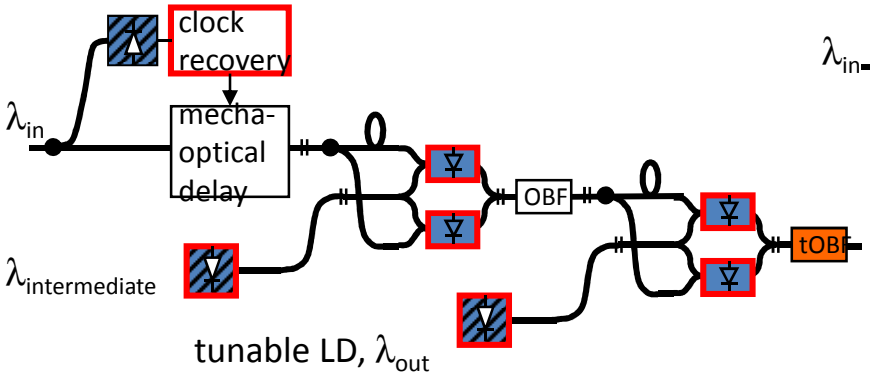
Performance of PSMB with different sharing ratio



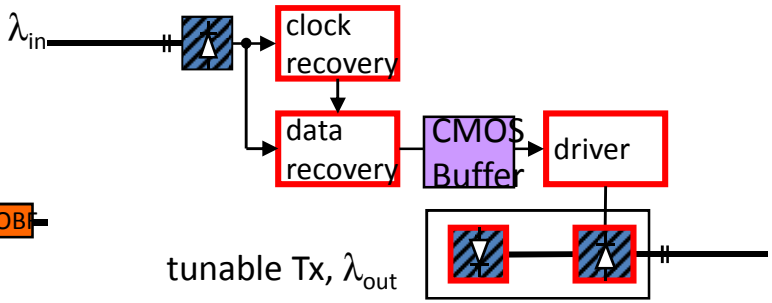
source: J. Kevin Lee, KAIST ICC workshop 2010

Hybrid optical packet node architecture (PSMB)

Wavelength Converters



OOO wavelength converter (using SOA)



OEO wavelength converter

Item	Power (W)		Relative cost	
	10G	40G	10G	40G
Cooled laser diode	0.6	0.6	0.35	0.35
Cooled tunable laser diode	0.8	0.8	0.5	0.5
Adjustable optical delay	0.2	0.2	0.1	0.1
4 cooled SOAs	1.2	1.2	1.4	1.4
Rx CDR	0.2	1.2	0.15	0.6
PIN-TIA	0.13	0.30	0.30	1.0
Total	3.13	4.5	2.8	3.95

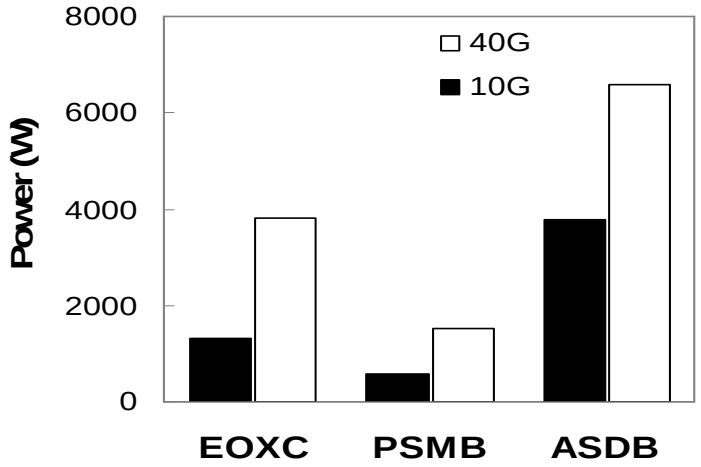
Item	Power (W)		Relative cost	
	10G	40G	10G	40G
DML diode	0		0.35	
DML driver	0.42		0.20	
EML diode with TEC		1.00		0.7
EML driver		0.60		0.8
Tx-Rx Mux and CDR	0.25	1.50	0.15	0.6
PIN-TIA	0.13	0.30	0.30	1.0
Total	0.80	3.40	1.00	3.1

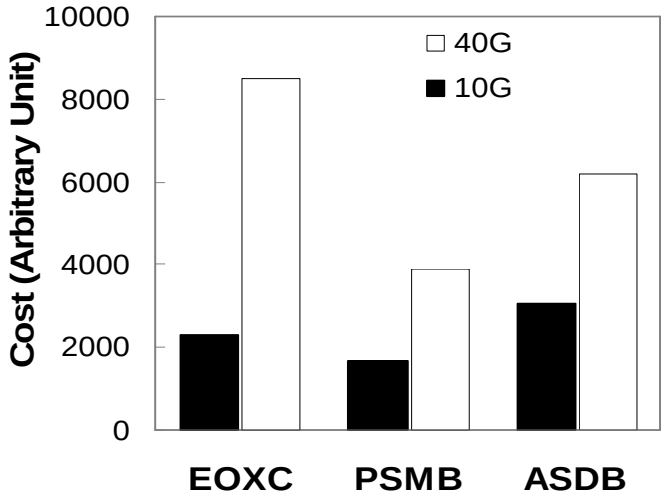
Table: Power & cost comparison of WCs using OEO & SOA

Power & Cost Comparison of PSMB & Exiting Architecture

Major Component	OEXC	PSMB	ASDB
Tunable WC			$2\,W\,(N+B)$
FDL			$\lceil WB/\,W_{FDL} \rceil$
SOA		$W\,(N\text{-}B)$	$W\,B$
Electro-optic switch (2x2)		$W\,N\,(\log_2 N+1)$	
Electronic switch (2x2 at 10 or 40G)	$W\,N\,(\log_2 WN$ - ½)	$W\,B\,(\log_2 WB$ - ½)	
Interface (E/SR & SR/E)	$W\,N$	$W\,B$	
TRx (SR/E/O & O/E/SR)	$W\,N$	$W\,B$	

Table: Major components counts in Node Models





Target & Achievement

Target	Achievement
Moving towards the Hybrid technology	Obtained by using shared electronics buffer and Optical switch fabric
Reduce Power consumed	About 50% reduction is achieved using the proposed Node Architecture
Reduce on total cost	About 1/3 cost reduction achieved
Changing the Wavelength converter Technology	From OOO to OEO wavelength converter
Modifying the Present Node Architecture (ASDB)	Proposed a new Node architecture (PSMB)

Further Approaches To be Taken

- Modifying in the electronics switch part

- Buffer the input data on the basis of lambda so if needed then use the wavelength converter and if not needed of the conversion bypass it.

- This features not only reduce the number of wavelength converter but also reduces the number of locking of different wavelength

- As each locking process will have some amount of more power consumption it can reduce the power as it is reducing the number of converting different frequency

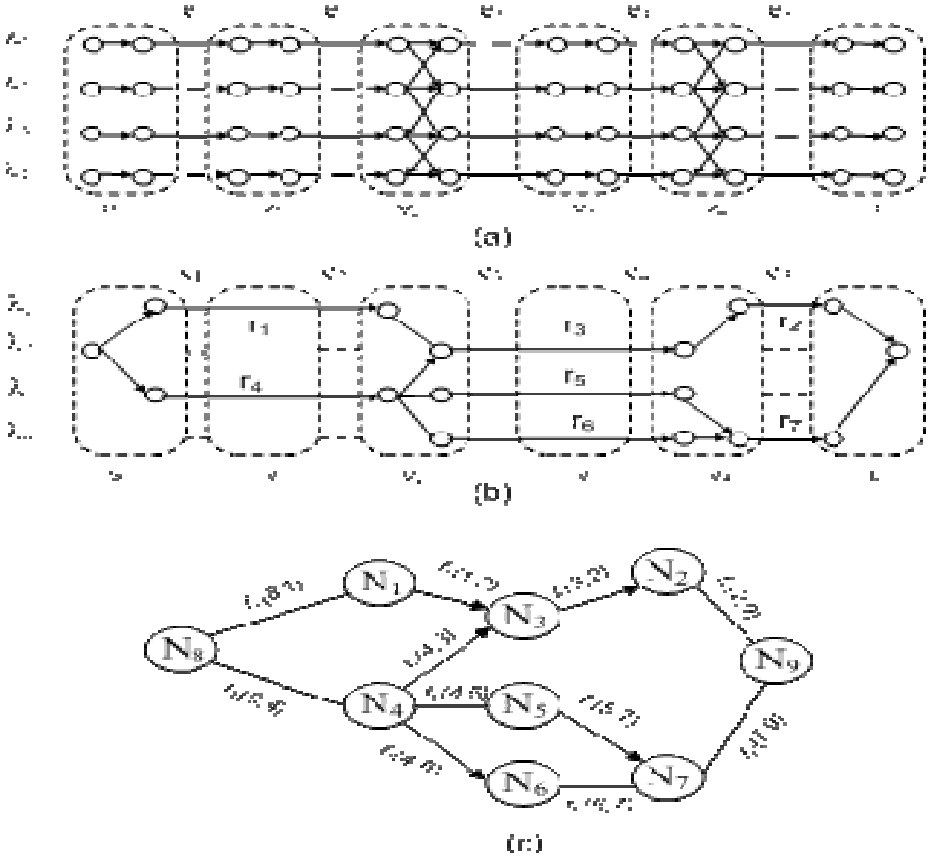
- Finally obtain the power reduction up to 75% and cost reduction to the 30% than that of traditional node architecture

Traffic grooming modification for reducing number of WCs

Source : N8
Destination : N9
Paths : {8,1,3,2,9}
{8,4,3,2,9}
{8,4,5,7,9}
{8,4,6,7,9}

Groomed paths:
{8,4,5,7,9}
{8,4,6,7,9}

Reduced 1 wavelength converter



Representation of a physical route from source to destination
(a) Wavelength layered model (b) lambda run model (c)) lambda run graph

Conclusion

- Only photonics solution seem not to help so approach should be towards Hybrid Technology
- Shows the significant power and cost saving with proposed PSMB Switching Node
- Usage of shared Buffer and Wavelength converter can minimize the power
- Modifying the WCs from OOO to OEO WCs
- Further improvement can be made by reducing number of wavelength converter and minimizing the transition of converted wavelength