Scheduling algorithms and cost model for optical switching matrix

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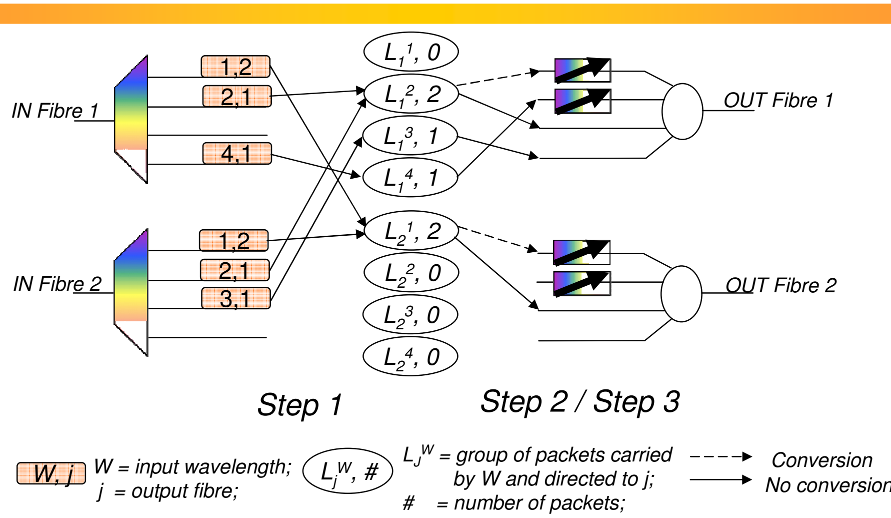
Scheduling algorithms

Scheduling algorithms: requirements

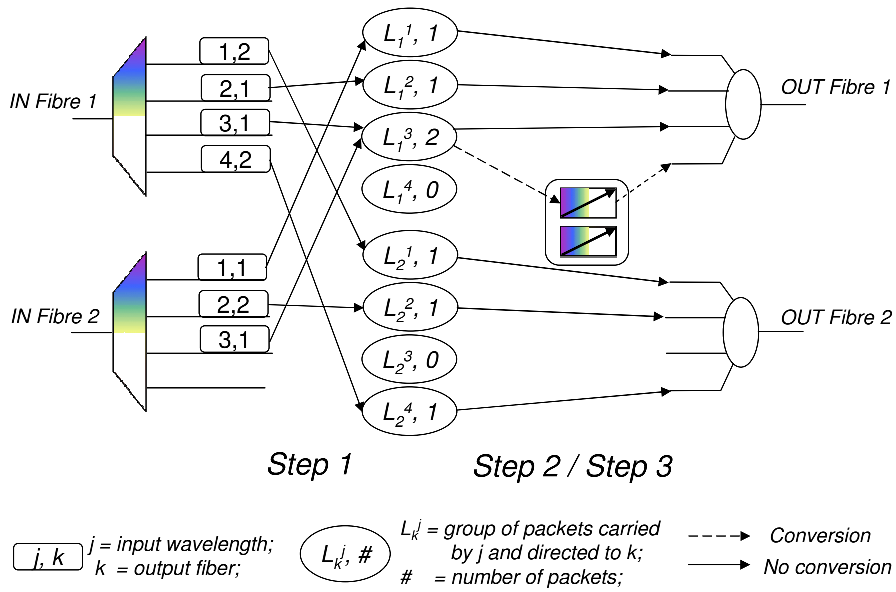
- Scheduling algorithms manage optical packet forwarding through the switching matrix
- Scheduling algorithms in synchronous context must be carefully designed
  - low computational time required
    - all incoming packets must be scheduled in a time slot
    - Computational complexity as a function of N and M should be evaluated
  - a scheduling algorithm aims at optimizing resource usage to reduce packet loss
    - low packet loss
  - Fairness among the fibers and wavelengths

Example: scheduling algorithm for SPL



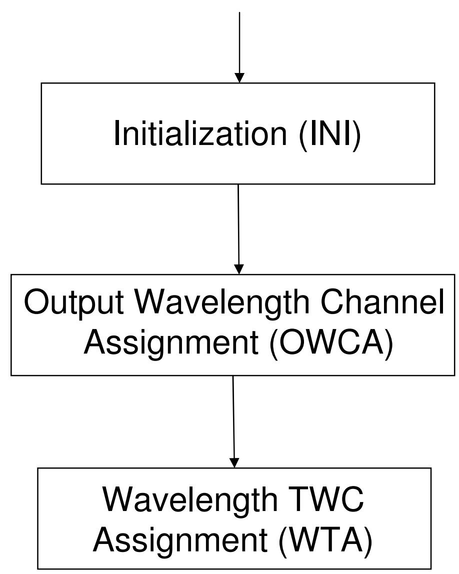
- phase 1: input channels are sequentially considered and packets coming on the same wavelength and directed to the same output fiber are grouped in the same set
- phase 2: packets in the same group contend for the same output channel
  - One and only one packet per set can be sent without wavelength conversion

Example: scheduling algorithm for SPN



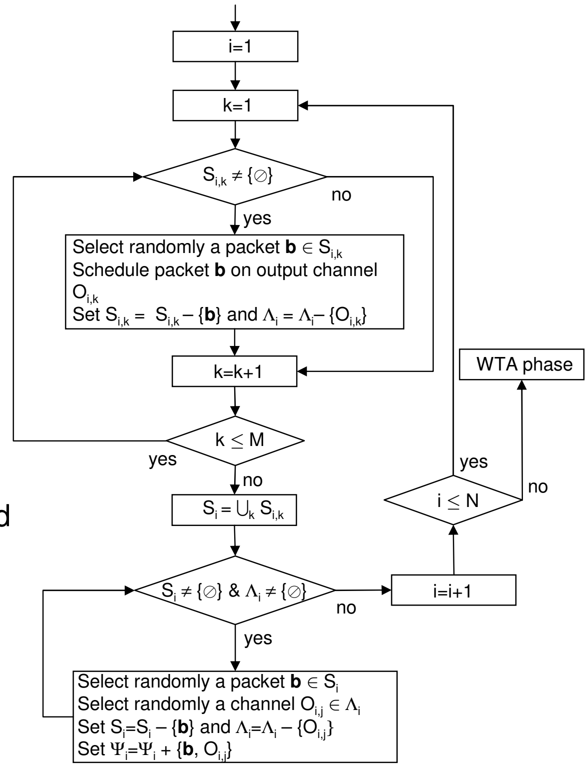
Scheduling algorithm for SPN: flow chart (1)

- 3 different phases with different computational complexity:
  - Initialization
  - Output Wavelength Channel Assignment
  - Wavelength TWC Assignment



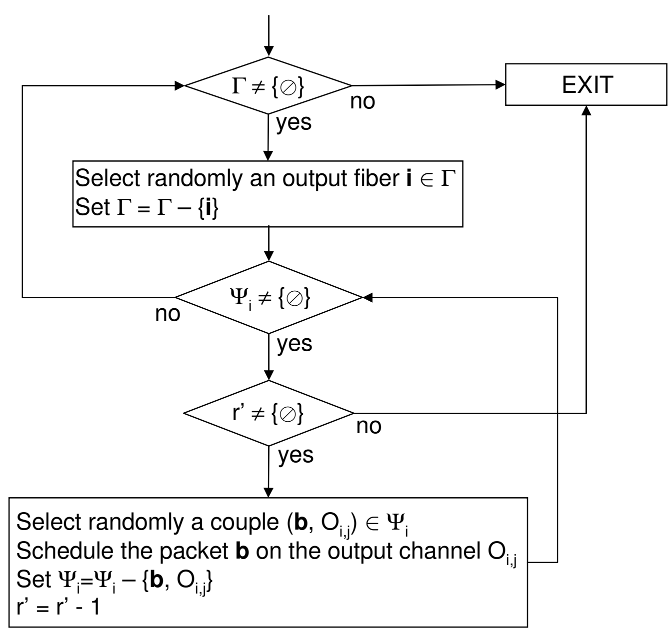
Scheduling algorithm for SPN: flow chart (2)

- $S_{i,k}$ (i=1, …, N), (k=1, …, M) contains packets carried by wavelength k and directed to output fiber i
- $O_{i,k}$ (i=1, ⋯, N), (k=1, ⋯, M) output channel related to wavelength k on output fiber i
- S_i (i=1, ⋯, N) contains those packets directed to output fiber i which need wavelength conversion
- Λ_i (i=1, ⋯, N) contains the free output wavelength channels on output i
- Ψ_i (i=1, ⋯, N) contains packets directed to I which must be converted
- Γ contains the output fibers not already considered in the current time slot
- r' number of TWCs available during the execution of the algorithm



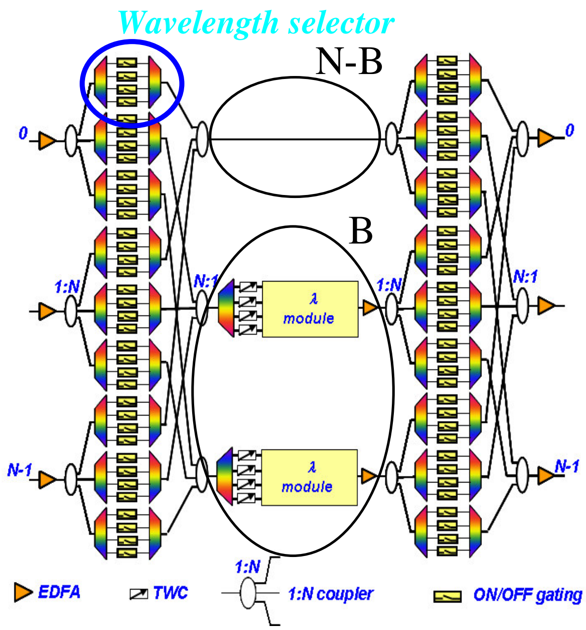
Scheduling algorithm for SPN: flow chart (3)

- phase 1 computational complexity: O(NM)
- Phase 2: computational complexity: O(NM)
- Phase 3 computational complexity: O(N+r)

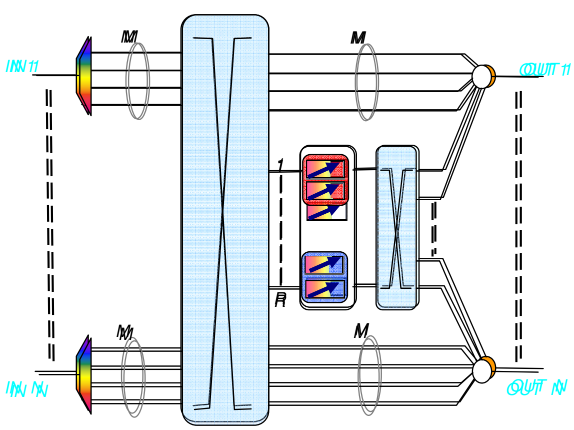


S-λ-S multi-stage architecture

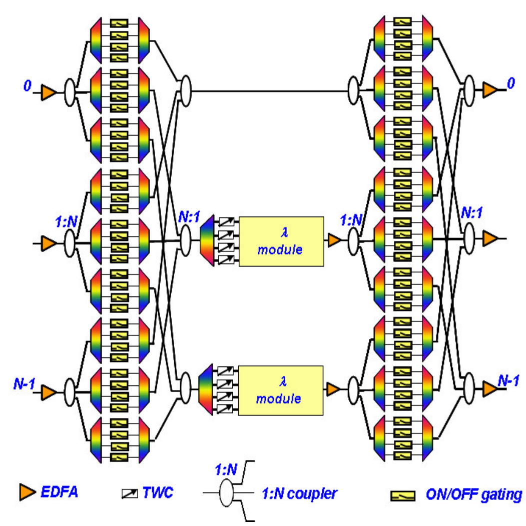
- N in/out fibers carrying M wavelengths
- Optical components: EDFA, SOA, MUX/DEMUX, TWC…
- First stage (S): broadcast & select, space stage to reach TWCs
- Second stage (λ): conversion stage
  - TWCs grouped in blocks
  - Each TWC in a block dedicated to a given wavelength
  - Some blocks (N-B) are replaced by fibers
- Third stage (S): space stage to reach the output fibers



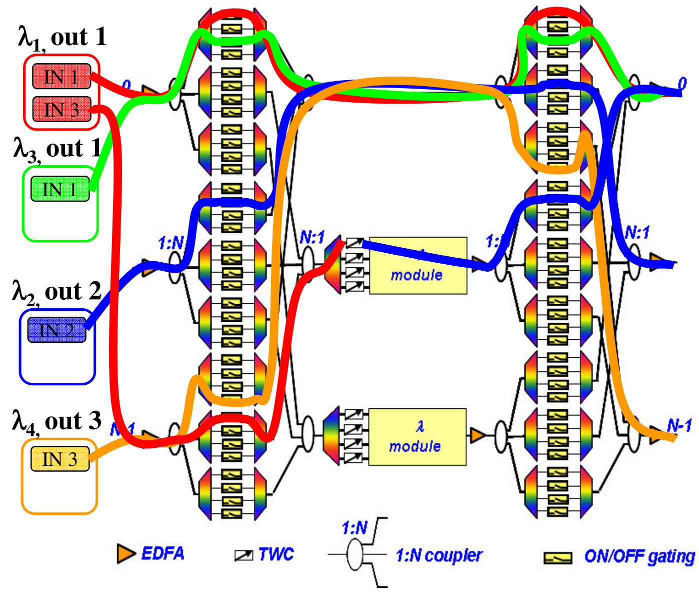
SPN and S-λ-S



Strictly Non-Blocking (SNB) Space Switching Matrix

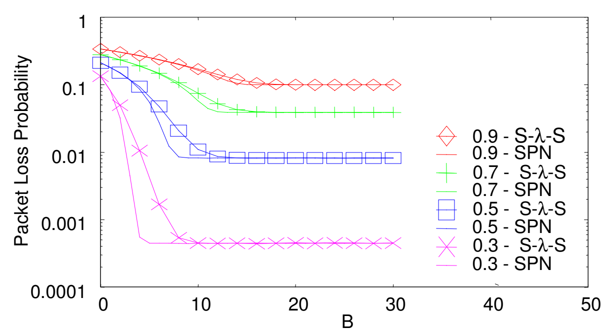


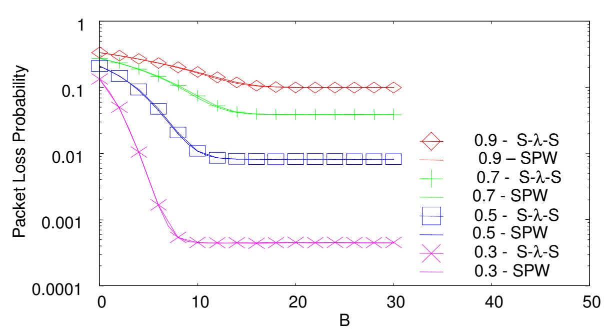
Scheduling algorithm for S-λ-S



Comparison among SPN, SPW and S-λ-S

- Same asymptotic value
- SPN provides best performance
- SPW e S-λ-S provide almost the same performance





Cost model

Switch cost model

- Definitions:
  - N_{SOA}^{A} number of SOAs for a generic architecture A
  - N_{TWC}^{A} : number of TWCs for a generic architecture A
  - C_{SOA} : cost of an SOA
  - C_{TWC} : cost of a TWC
- Cost of architecture A:
  - $C_{A} = N_{SOA}^{A} C_{SOA} + N_{TWC}^{A} C_{TWC}$
  - Parametric evaluation of cost:
  - $C_{TWC} = \alpha C_{SOA}$ $\quad C_{A} = (N_{SOA}^{A} + \alpha N_{TWC}^{A}) C_{SOA}$

Cost comparison

- Two architectures (A and B) relying on the same kind of TWCs are considered:
  - $C_A = (N_{SOA}^A + \alpha N_{TWC}^A)\, C_{SOA}$
  - $C_B = (N_{SOA}^B + \alpha N_{TWC}^B)\, C_{SOA}$
- Architecture ***A is less expensive than B*** ($C_A < C_B$) when:
  - $N_{SOA}^A + \alpha N_{TWC}^A < N_{SOA}^B + \alpha N_{TWC}^B$
- Find the limiting value of α_{th} satisfying the previous condition

$$\alpha_{th} = \frac{N_{SOA}^A - N_{SOA}^B}{N_{TWC}^B - N_{TWC}^A}$$

- This condition results in
  - $\alpha > \alpha_{th}$ when $N_{TWC}^A < N_{TWC}^B$
  - $\alpha < \alpha_{th}$ when $N_{TWC}^A > N_{TWC}^B$

SPN and S-λ-S comparison

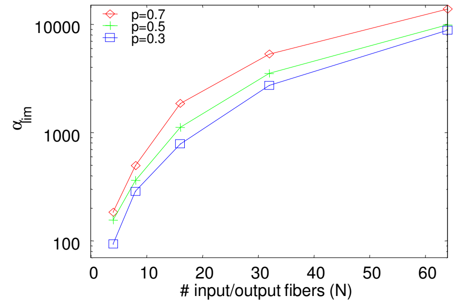
- SPN is less costly than S-λ-S when:
  - $(N_{SOA}^{SPN} + \alpha N_{TWC}^{SPN}) < (N_{SOA}^{S\text{-}\lambda\text{-}S} + \alpha N_{TWC}^{S\text{-}\lambda\text{-}S})$
- *Here* $N_{TWC}^{S\text{-}\lambda\text{-}S} - N_{TWC}^{SPN} > 0$ and $N_{SOA}^{SPN} - N_{SOA}^{S\text{-}\lambda\text{-}S} > 0$

$$\Rightarrow \quad \alpha > \alpha_{th} = \frac{N_{SOA}^{SPN} - N_{SOA}^{MS\text{-}SPW}}{N_{TWC}^{MS\text{-}SPW} - N_{TWC}^{SPN}}$$

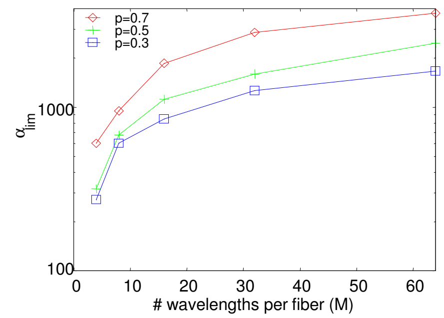
- $N_{TWC}^{S\text{-}\lambda\text{-}S}$ and N_{TWC}^{SPN} are the minimum number of TWCs to obtain the asympotic value of PLP
- N_{SOA}^{SPN} and $N_{SOA}^{S\text{-}\lambda\text{-}S}$ are given by:
  - $N_{SOA}^{SPN} = (NM)^2 + NR(2M-1)$
  - $N_{SOA}^{S\text{-}\lambda\text{-}S} = 2N^2M$

Value of α_{th} as a function of N and M

- Value of α_{th} varying:
  - the number of fibers in case M=16, p=0.3, 0.5, 0.7
  - The number of wavelengths per fiber in case N=16, p=0.3, 0.5, 0.7



- The number of wavelength converters is chosen as the minimum to obtain the asymptotic loss probability



- SPN less costly than *S*-λ-*S* when $\alpha > \alpha_{th}$

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