A Review of Routing and Wavelength Assignment Algorithms and Some Research Challenges for Optical WDM Networks

by:

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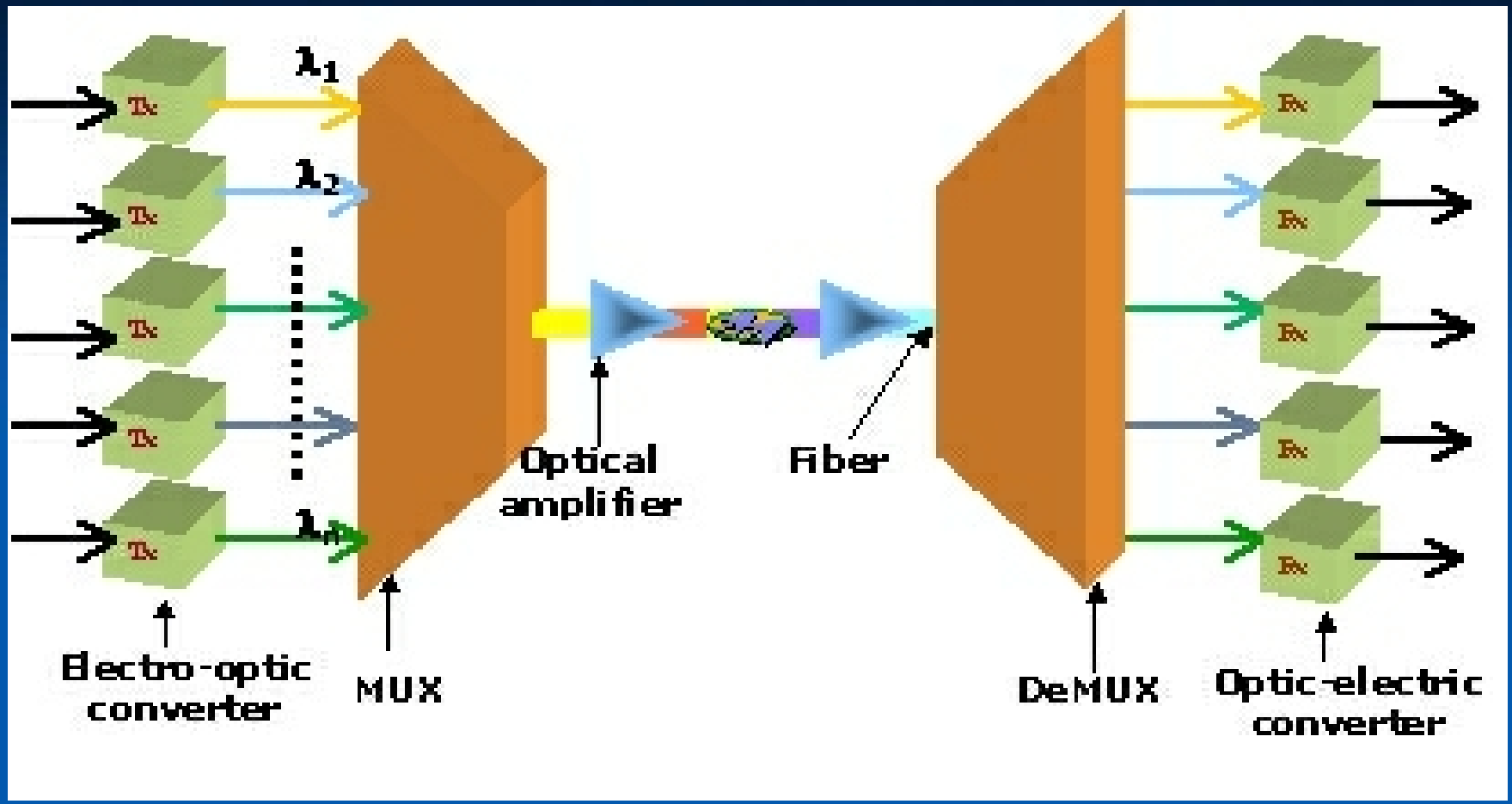
Presentation Breakdown

- Introduction
- Previous Research
  - Off-line Algos
  - On-line Algos
- Current Research
- Future Research Challenges
- Summary
- Conclusion

Introduction

- True power of Internet, WWW & emerging GRID computing can't be unleashed without high capacity optical networks
- WDM in optical networks most preferred tech today
  - IP over corase WDM
  - IP over DWDM

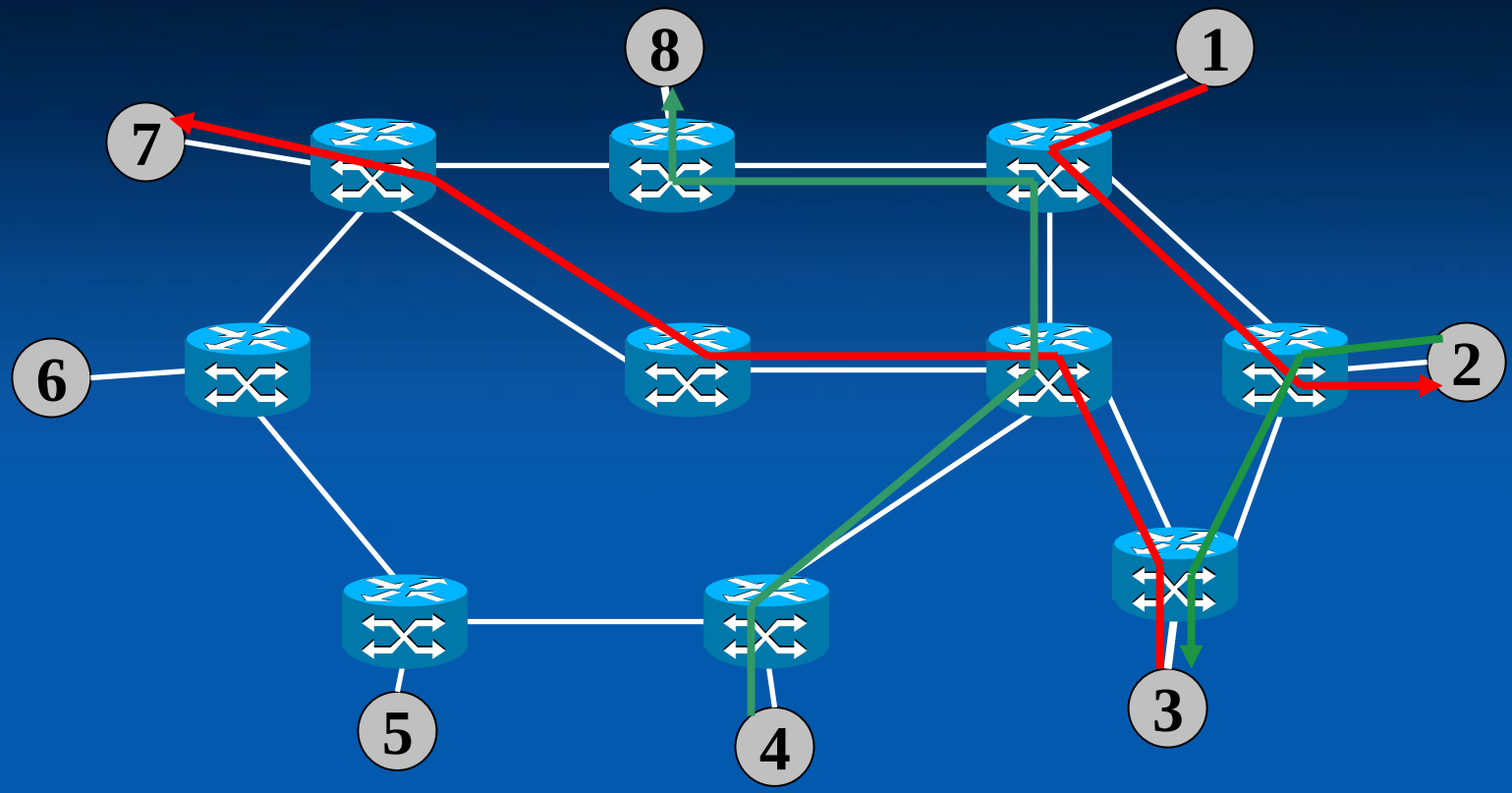
WDM/DWDM


Tx
Tx
Tx
Tx
Tx
λ_1
λ_2
λ_n
Optical amplifier
Fiber
Rx
Rx
Rx
Rx
Rx
Electro-optic converter
MUX
DeMUX
Optic-electric converter

WDM/DWDM

- Sends multiple wavelengths on a single fiber in WDM networks
- Provides n times the bandwidth where n is the total no. of wavelengths available on the fiber
- A light path is an all optical path (no O-E-O conversion) from source to destination in wavelength routed networks

Example of Wavelength routed network



Access Node

Optical Switch

Light Path on wavelength λ1

Light Path on wavelength λ2

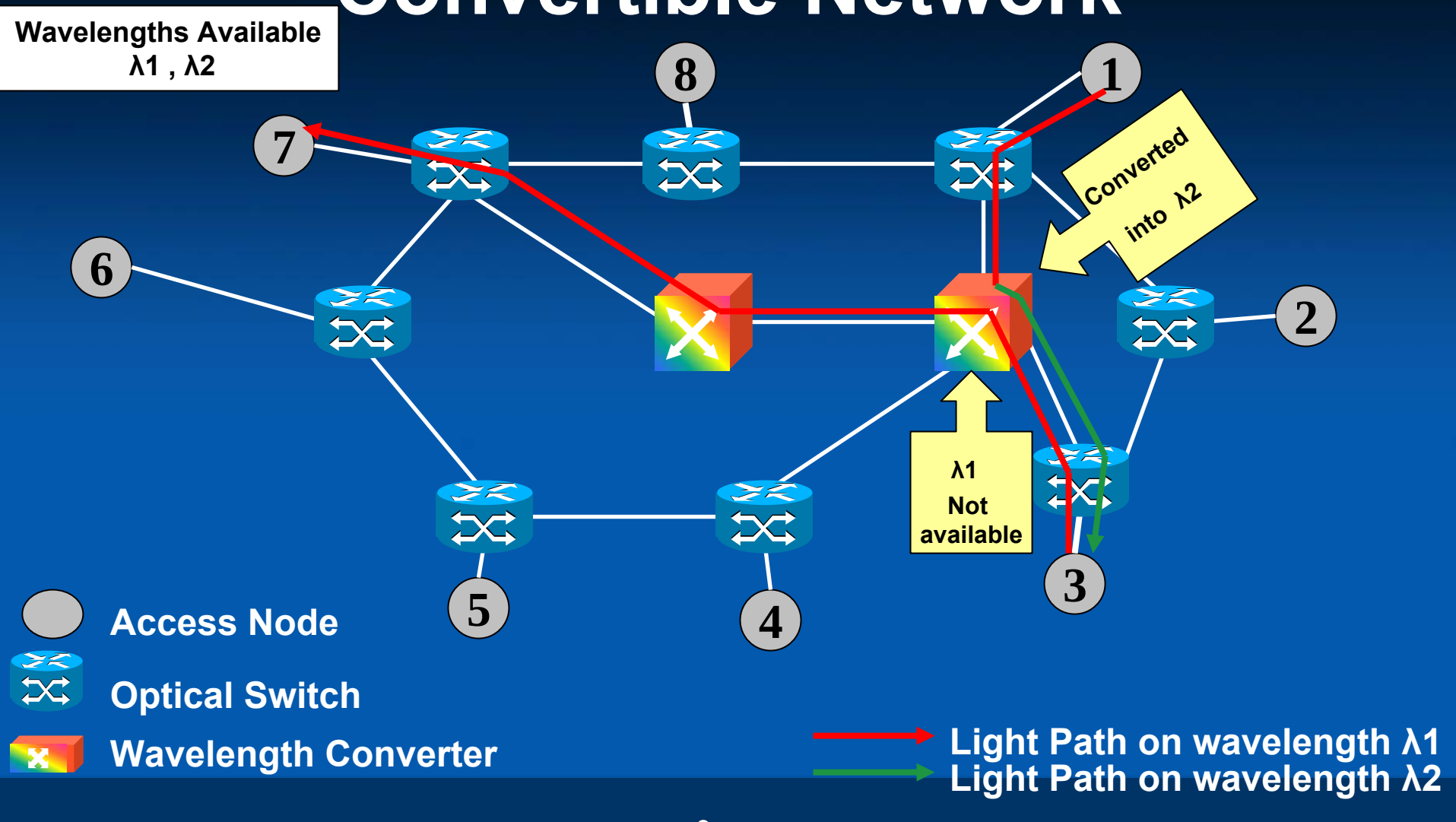
RWA Problem

- WDM networks have some peculiar challenges
  - RWA problem
- Routing and Wavelength Assignment (RWA) problem is defined as:
  - To select the best possible route from source to destination
  - To assign a wavelength to that route so that no two connections on the same link are assigned the same wavelength
  - Wavelength Continuity Constraint requires that a single light path must occupy the same wavelength on all of the links that it spans

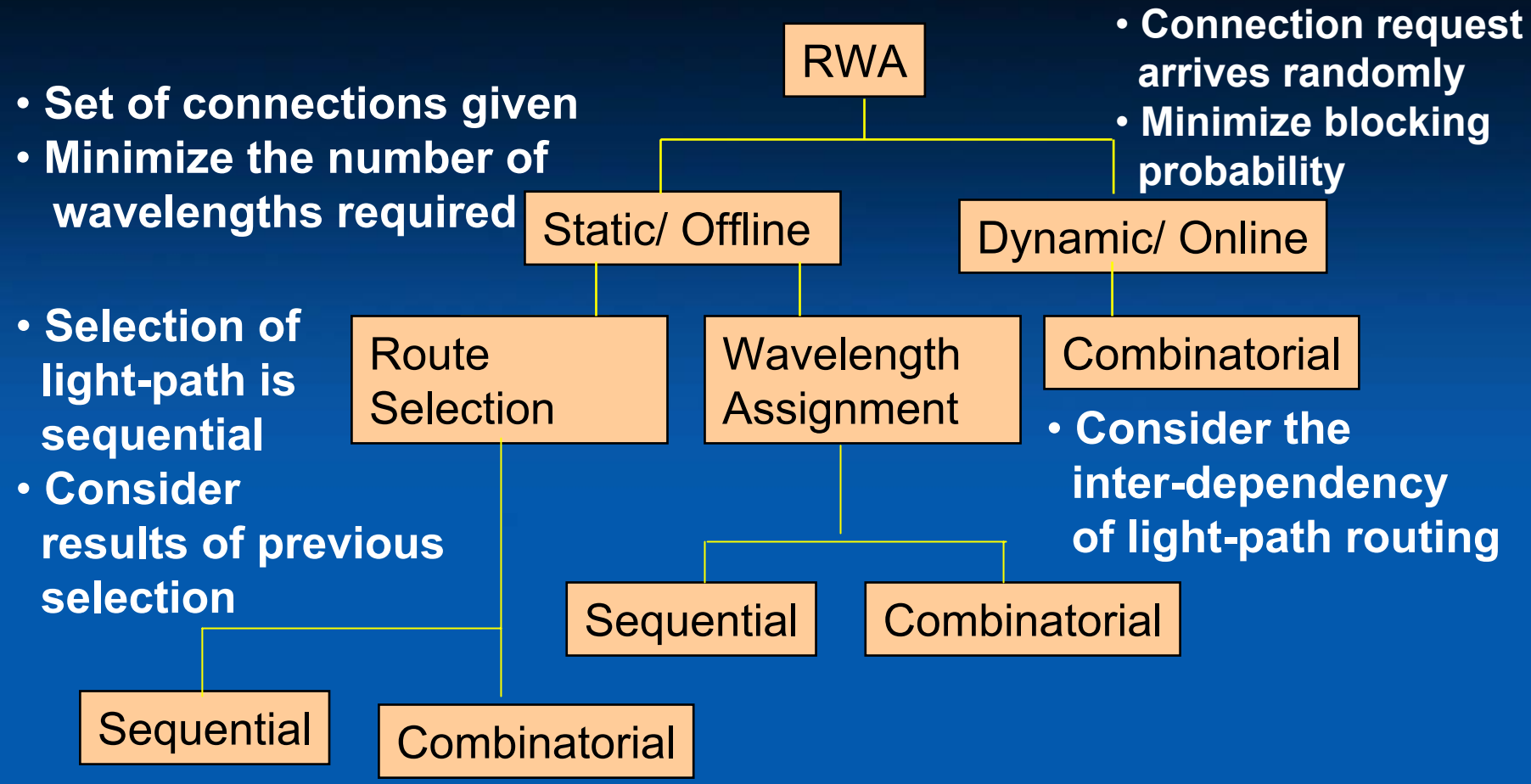
WDM Networks

- Wavelength Selective Network
  - No wavelength conversion
  - Wavelength Continuity Constraint (WCC) is strictly enforced
- Wavelength Convertible Network
  - Allows wavelength conversion on nodes
  - Wavelength Continuity Constraint (WCC) is relaxed either partially or fully
  - Wavelength converters – expensive piece of hardware

Example of Wavelength Convertible Network



Classification



Previous Research

Offline Algorithms

Online Algorithms

Goal for Offline Algorithms

- Minimize network resources
  - Number of wavelengths
  - Number of fibers

OR

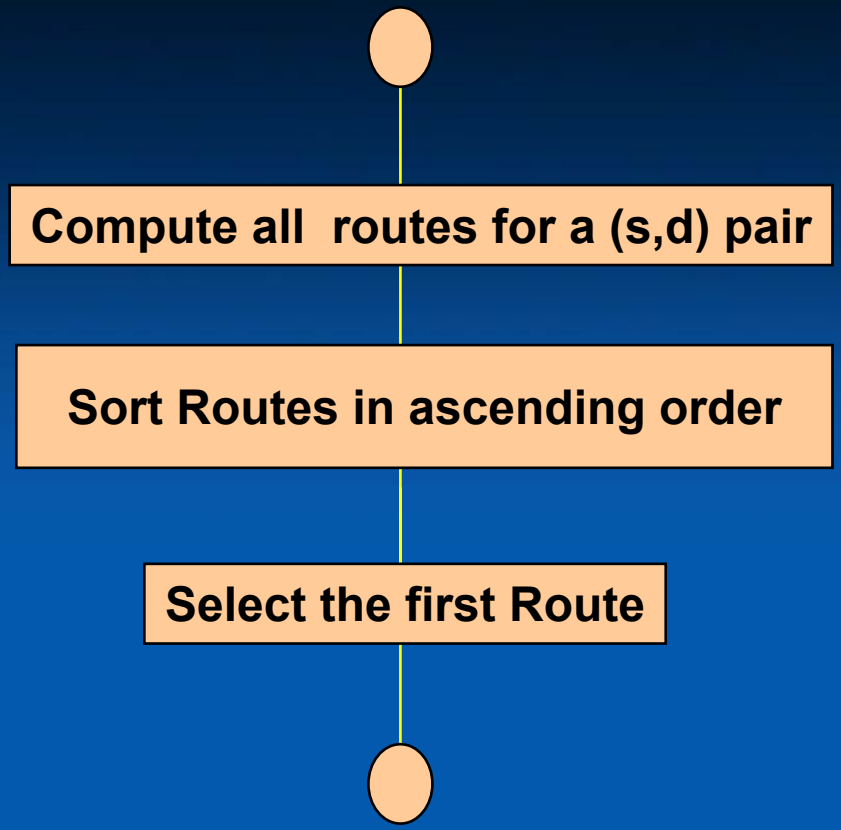
- Setup as many connections as possible for a given fixed number of wavelengths

Offline Algorithms

Route Selection (Sequential)

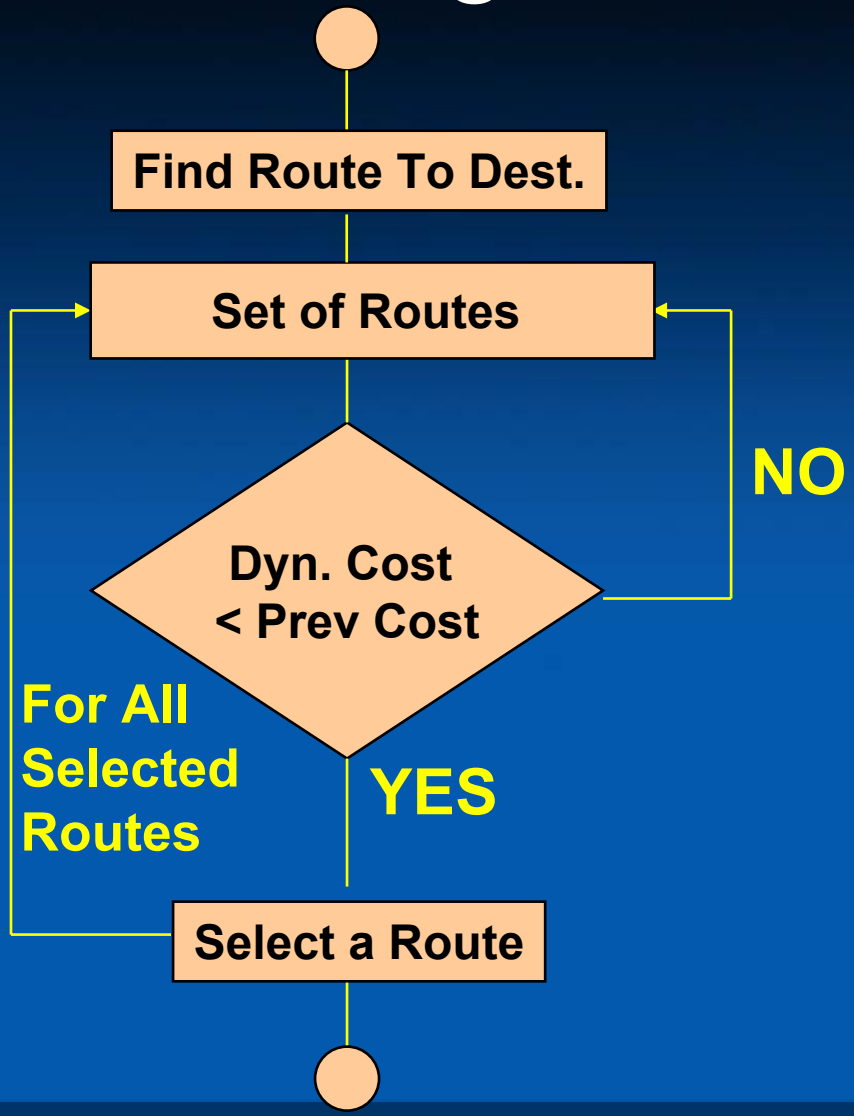
- Shortest Path
- Weighted Shortest Path
- K-shortest Path

Shortest Path



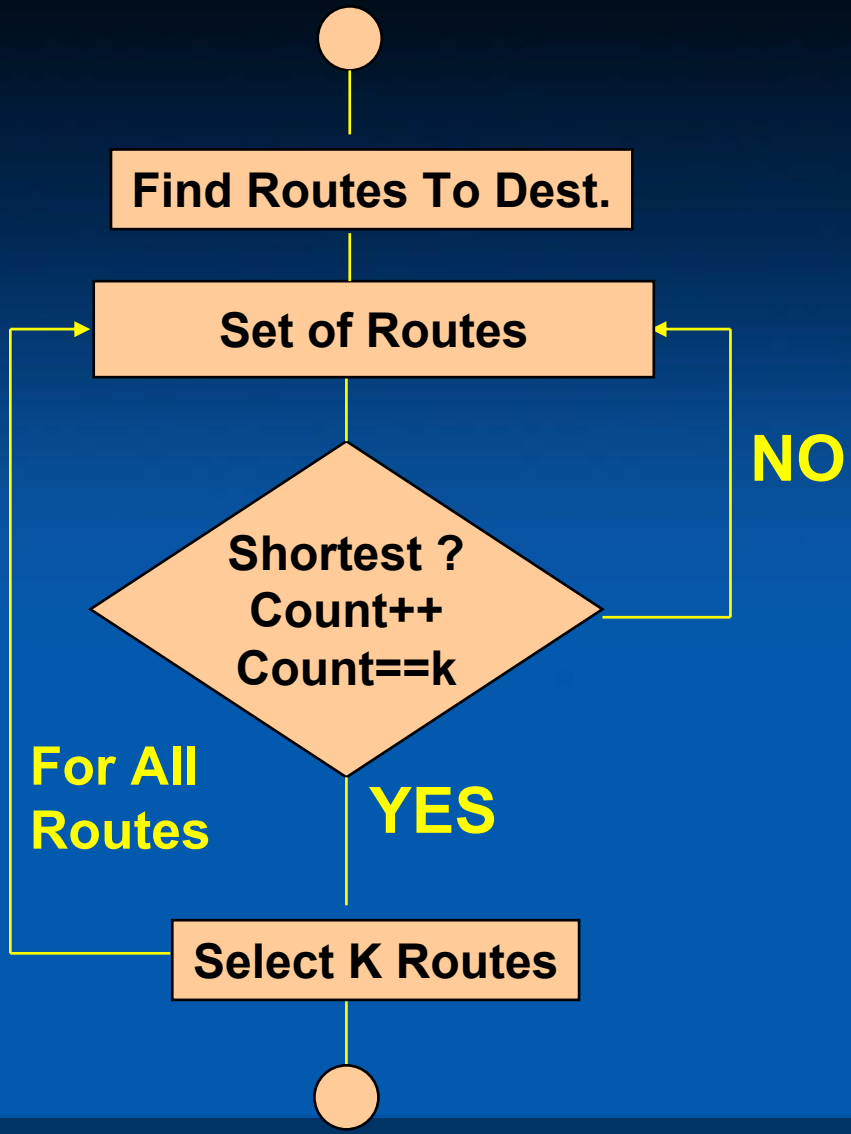
- Route between source & destination
- Cost is less than any other route
- Weights are static
- Generates one route

Weighted Shortest Path



- Shortest path algorithm
- Dynamically changing link cost associated with the number of routes established
- Requires Search Order
  - Largest Traffic First
  - Random

K - Shortest Path



- Shortest path algorithm
- More than one route i.e. k routes
- Flexibility in route selection
- Requires Selection Order
  - Routes are selected to obtain minimum cost
- Fault tolerant

Offline Algorithms

Route Selection (Combinatorial)

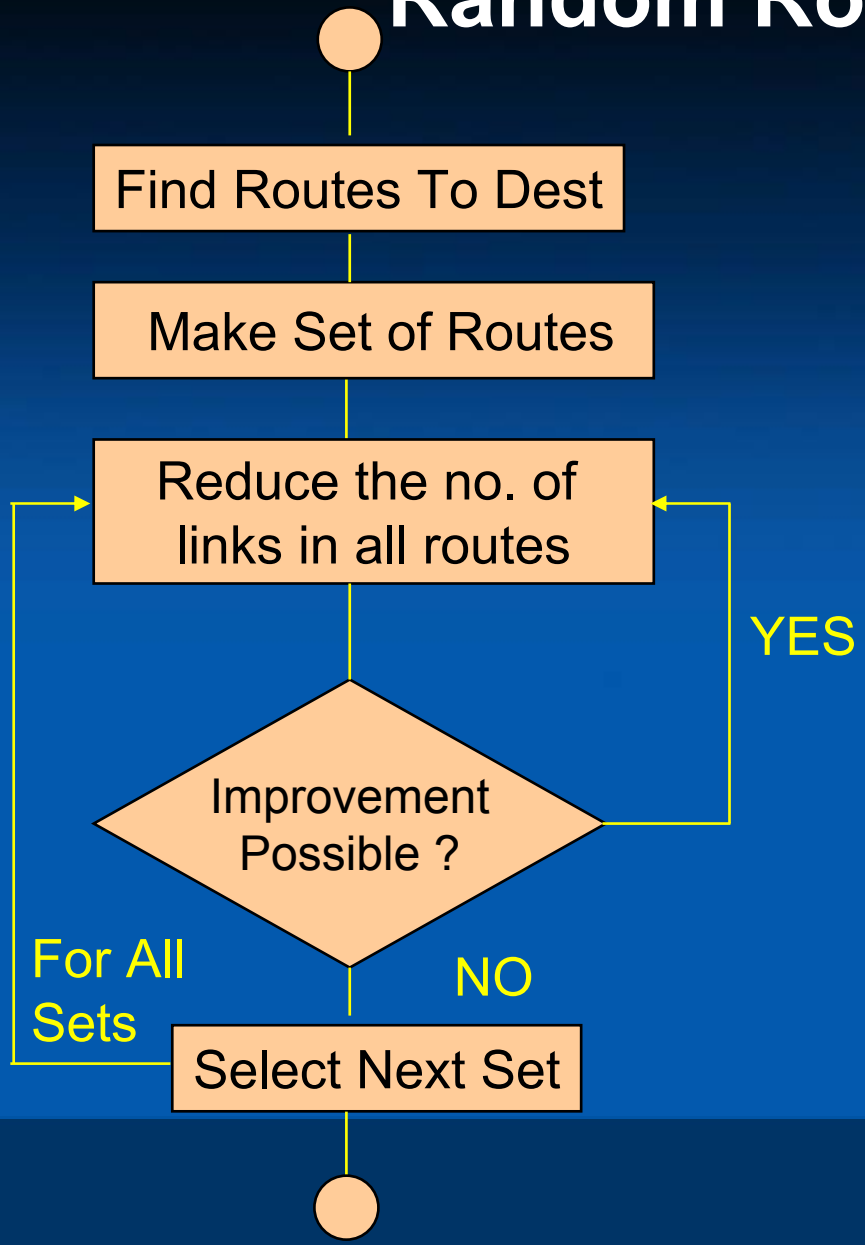
- Mixed Integer Program
- Random Rounding

Optimal Approach

–Mixed Integer Program[2]

- Modeled with the multi-commodity flow problem.
- Extremely difficult in terms of computational complexity.

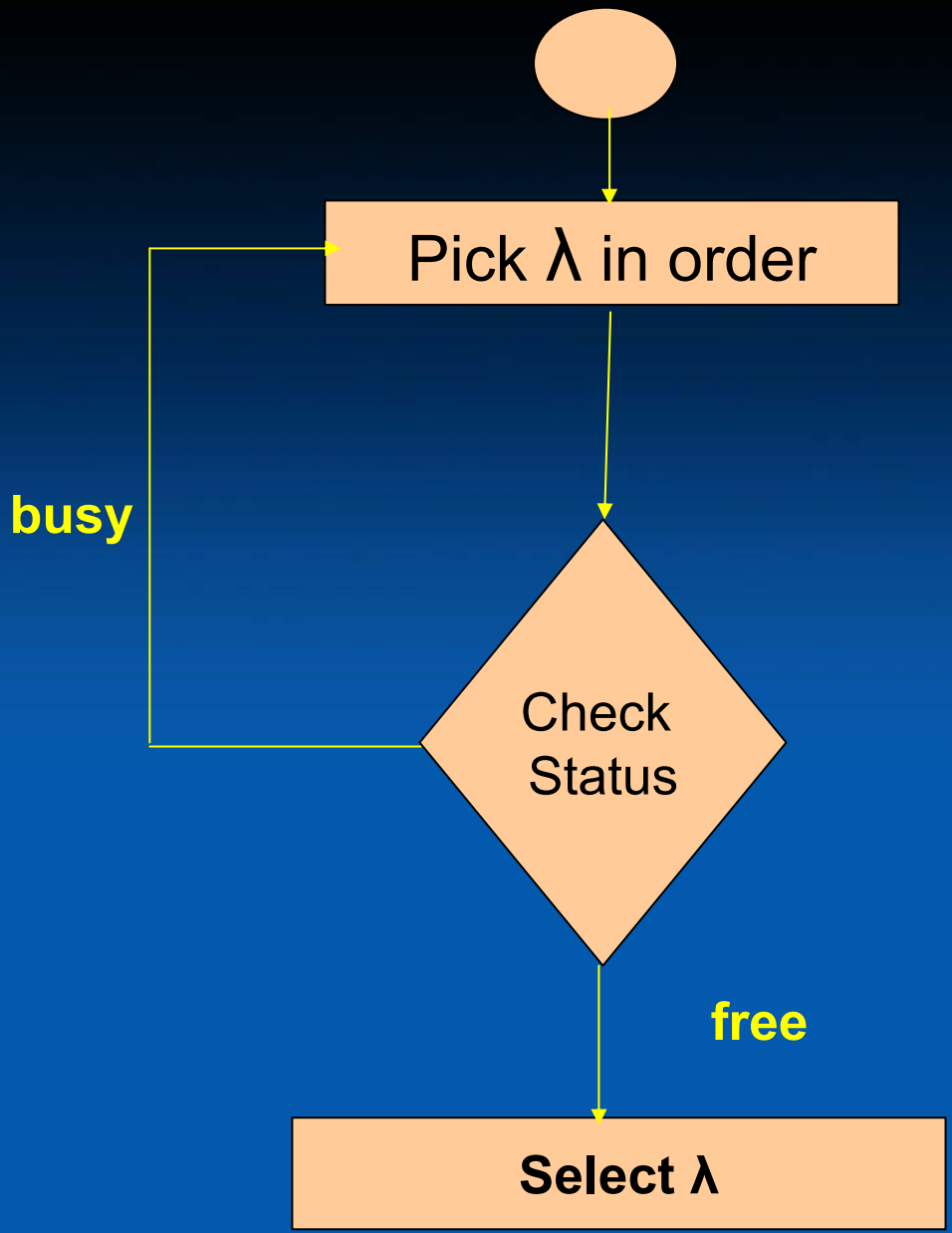
Heuristic Approach
Random Rounding Algorithm[2]



- Routing is performed repeatedly
- Links in routes are decreased
- Process continues till improvements are possible

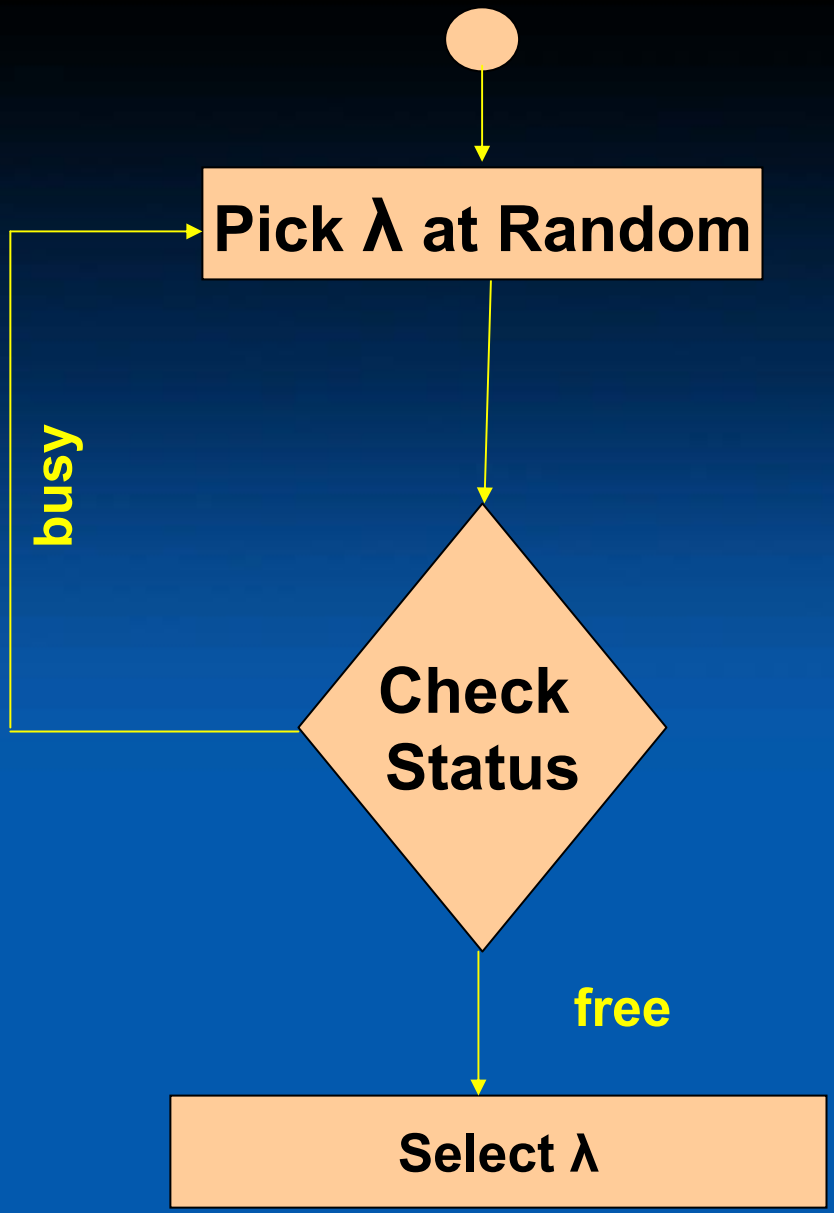
Wavelength Assignment (Sequential)

- First Fit
- Random
- Most-used
- Least-used
- Min-Product
- Least Loaded
- Max-Sum
- Relative Capacity Loss



First Fit

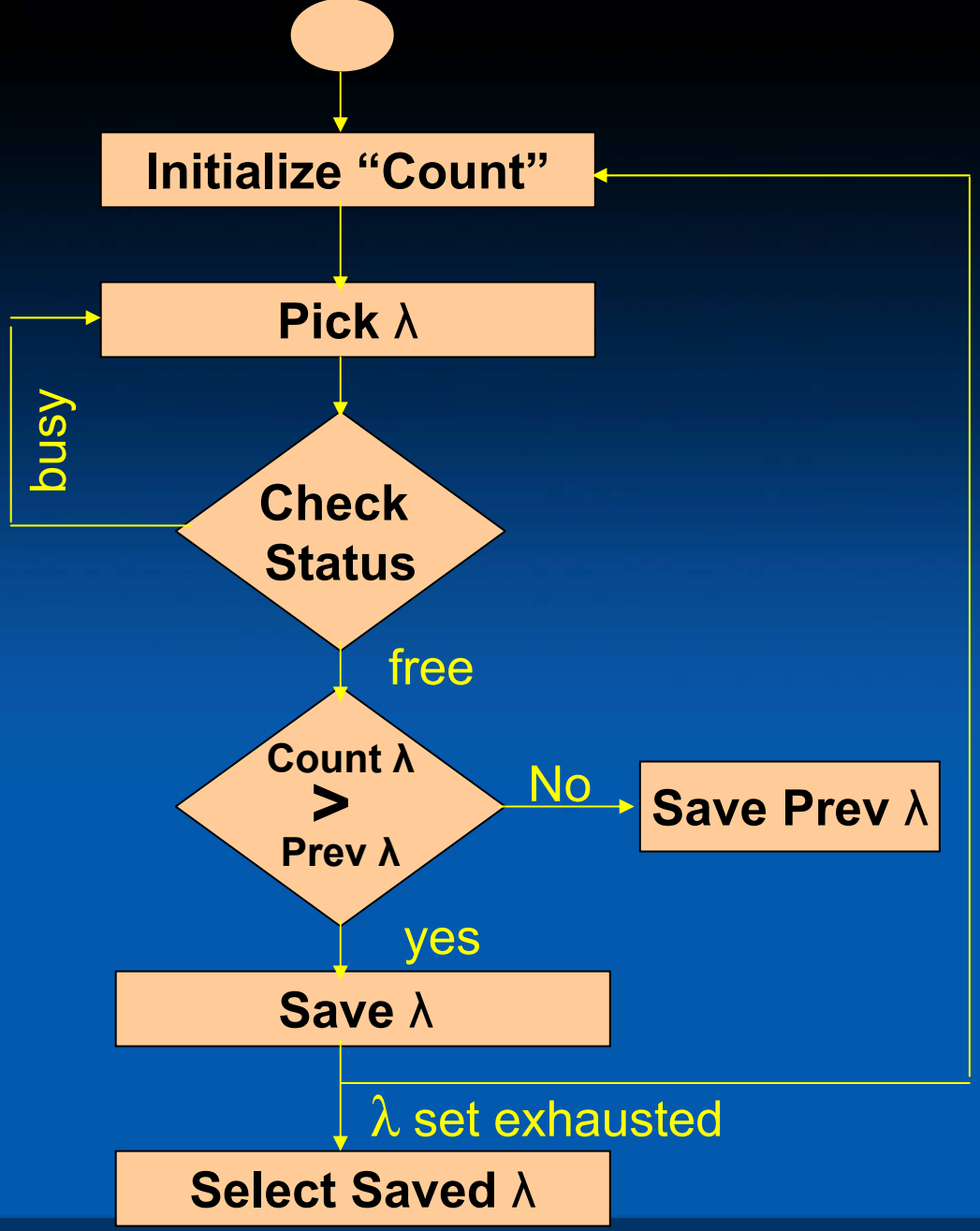
- First available wavelength is chosen
- No global information is needed
- Performs better in terms of Blocking Probability and fairness [4]



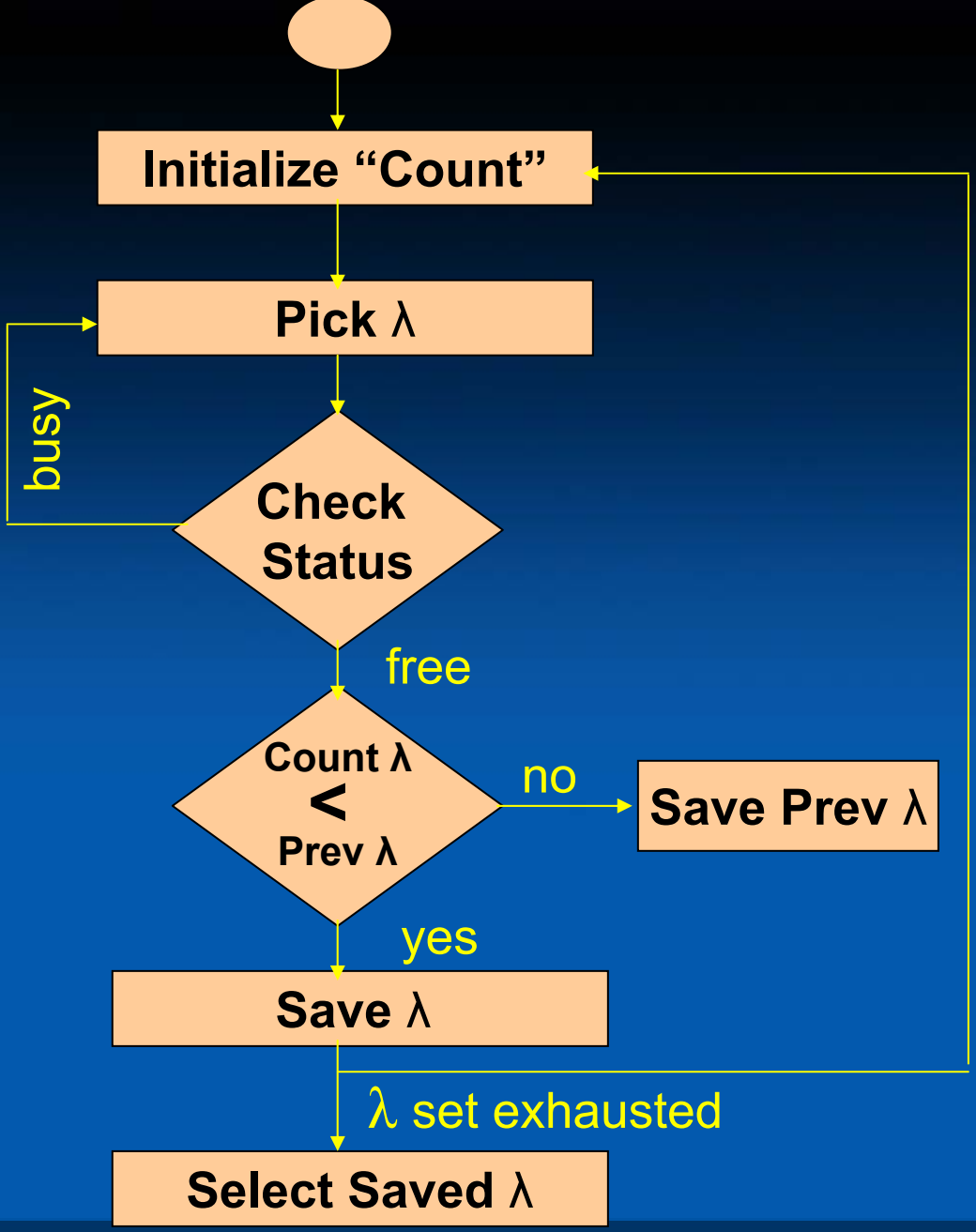
Random

- Wavelength is chosen at random
- No global information needed
- Performs worse than First Fit

Most-used



- Selects most-used wavelength in the network
- Requires network-wide wavelength usage information
- Packs connections into fewer wavelengths
- Slightly better than First Fit algorithm
- Overheads [4]
  - Storage
  - Communication
  - Computation



Least-used

- Selects least-used wavelength in the network
- Requires network-wide wavelength usage information
- Performs worse than random
- Overheads [4]
  - Storage
  - Communication
  - Computation

Multi-Fiber Algorithms

- Min-Product [4]
  - Pack wavelengths into fibers - minimize the number of fibers required
  - Chooses the lowest numbered wavelength
- Least-Loaded [4]
  - Selects the wavelength with the largest residual capacity on the most-loaded link along a route
  - When used in single-fiber networks, it chooses the lowest-indexed wavelength with residual capacity 1
  - It gives best performance in multi fiber case under high load

Multi-fiber Algorithms

- Max-Sum [4]
  - Considers all possible lightpaths and attempts to minimize the total capacity loss on all lightpaths
  - Also applicable in single-fiber networks
  - It work well when the load is high in both single and multiple fiber case
- Relative Capacity Loss [4]
  - Based on Max-Sum
  - Considers all possible lightpaths and attempts to minimize the relative capacity loss on all lightpaths