

# Routing strategies for multilayer network planning.



**POLITECNICO**  
MILANO 1863

**NOKIA** Bell Labs



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Bahram Hedayati

# What we are going to see:



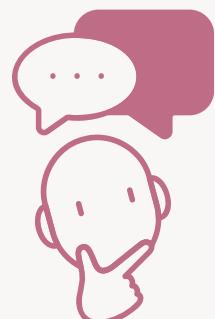
**Step 1**

Problem  
statement



**Step 2**

Approaches  
and examples



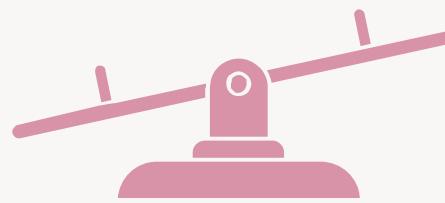
**Step 3**

Simulation



**Step 4**

Comparison



**Step 5**

Conclusion

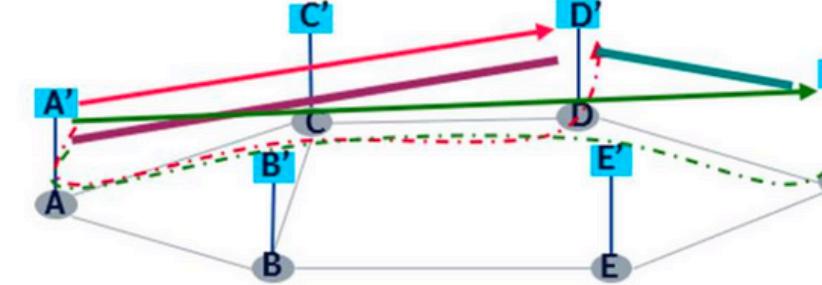




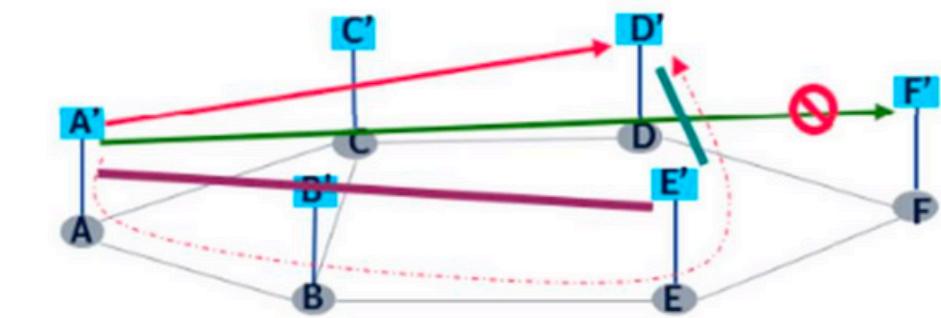
## Main goal:

Addressing the challenge of routing demands generated randomly  
In Top-Down and Bottom-Up approach and comparing them!

### Top-Down



### Bottom-Up



- Design the optical network by starting from the Demands
- Creating multiple lightpaths within a single optical fiber
- We have intermediate grooming
- Defines the necessary number and types of WDM trails.
- Routing OTN services through the previously built virtual topology.
- Service cannot be route ,it is blocked.



What we going to Compare?

## Objectives

Deployed WDM trails

Filling ratio

Average fiber occupation

Which constraint do we have?

## Constraints

WDM bandwidth: 4.8 THz in C-band

Max 96 channels at 50 GHz each

### WDM trail Capacity

500 Gb/s 1300 km reach

### Demand Rate

400 Gb/s 2500 km reach

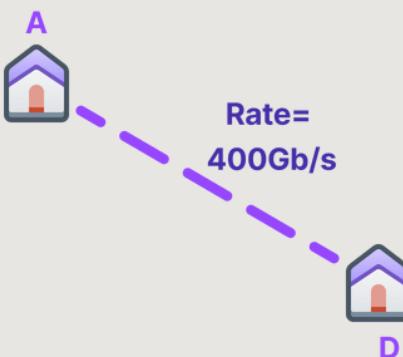
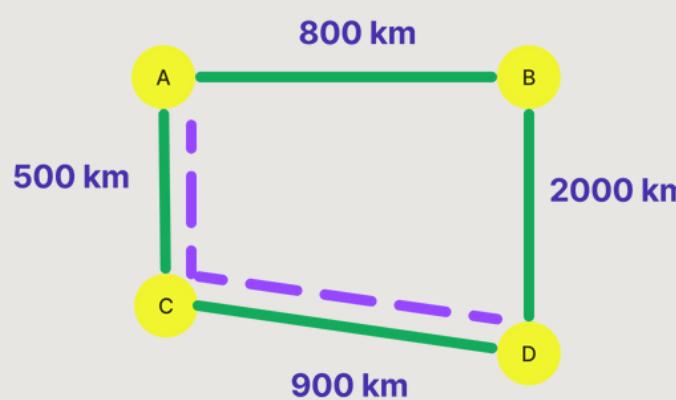
D1 = 100 Gb/s

D2 = 400 Gb/s

# Approaches examples

## Top-Down

D1: A → D 100 Gbps



## Constraints

WDM bandwidth: 4.8 THz in C-band

Max 96 channels at 50 GHz each

WDM trail

Capacity

Demand Rate

500 Gb/s 1300 km reach

400 Gb/s 2500 km reach

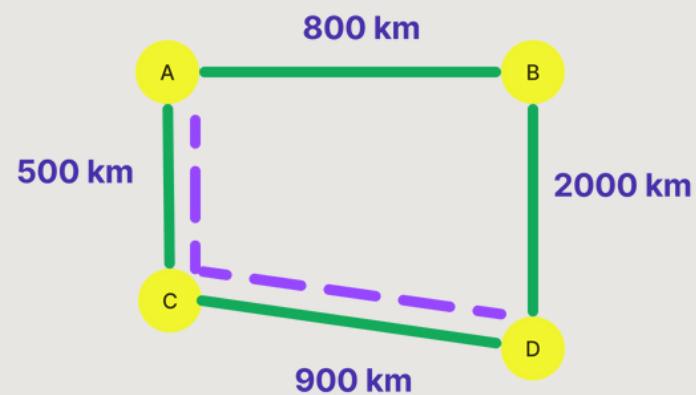
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D2 = 400 Gb/s

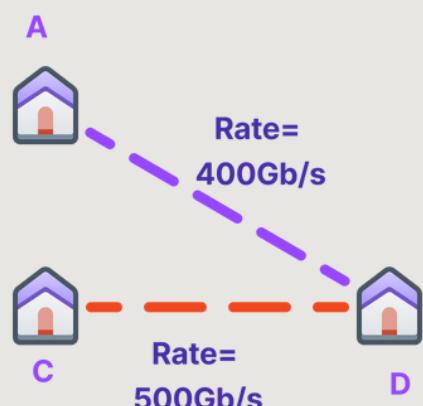
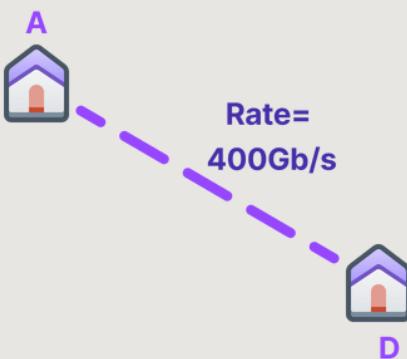
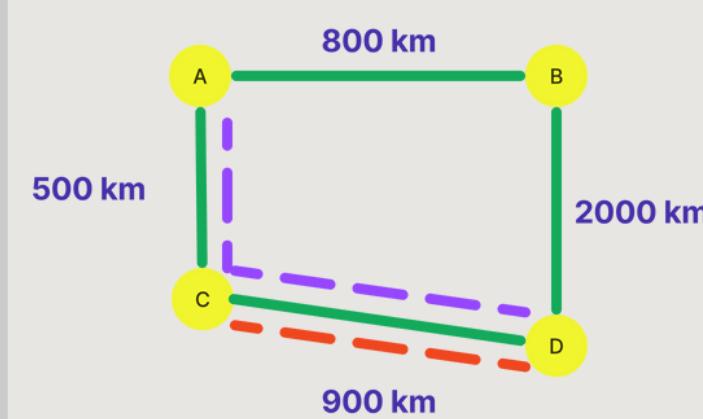
# Approaches examples

## Top-Down

D1: A -> D 100 Gbps



D2: C -> D 400 Gbps



## Constraints

WDM bandwidth: 4.8 THz in C-band

Max 96 channels at 50 GHz each

WDM trail

Capacity

Demand Rate

500 Gb/s 1300 km reach

400 Gb/s 2500 km reach

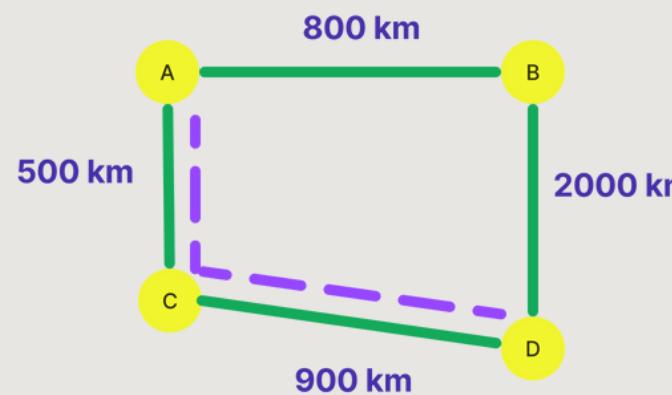
D1 = 100 Gb/s

D2 = 400 Gb/s

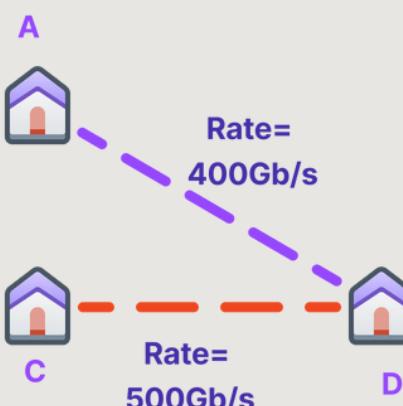
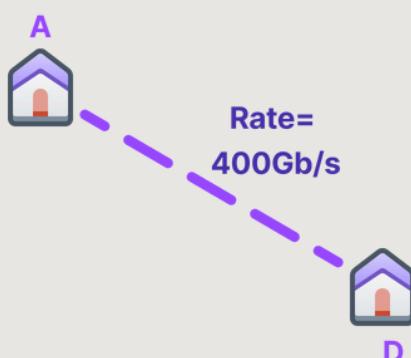
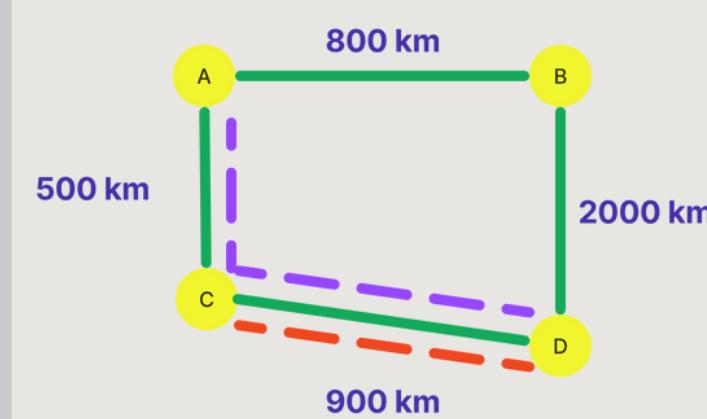
# Approaches examples

## Top-Down

D1: A -> D 100 Gbps

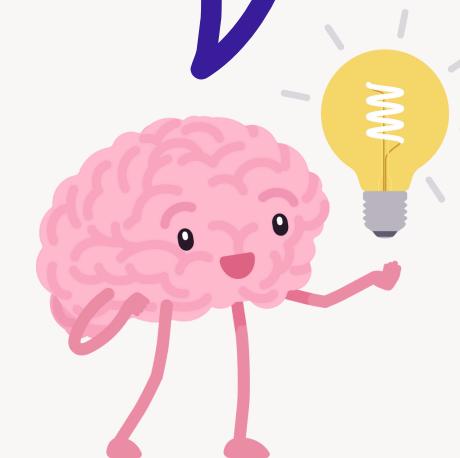


D2: C -> D 400 Gbps



### Grooming

Based on demands table  
We groom the ones with  
same S &D and data rate.



After grooming in a top-down approach, deploy new WDM trails until reaching a maximum of 96 WDM per link.

**Optimization algorithm**  
K- shortest path  
knapsack

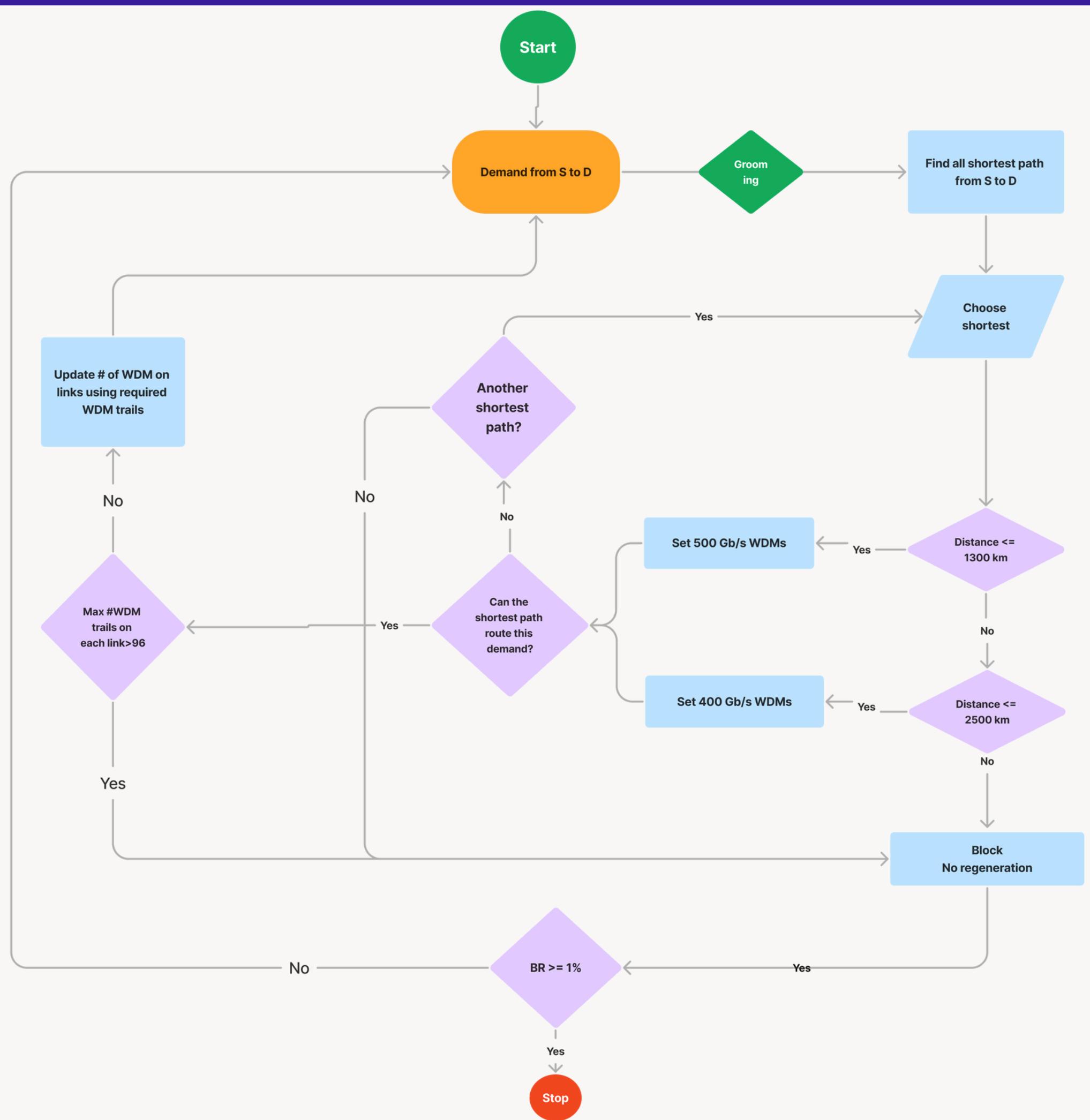


### Future Grooming Ideas

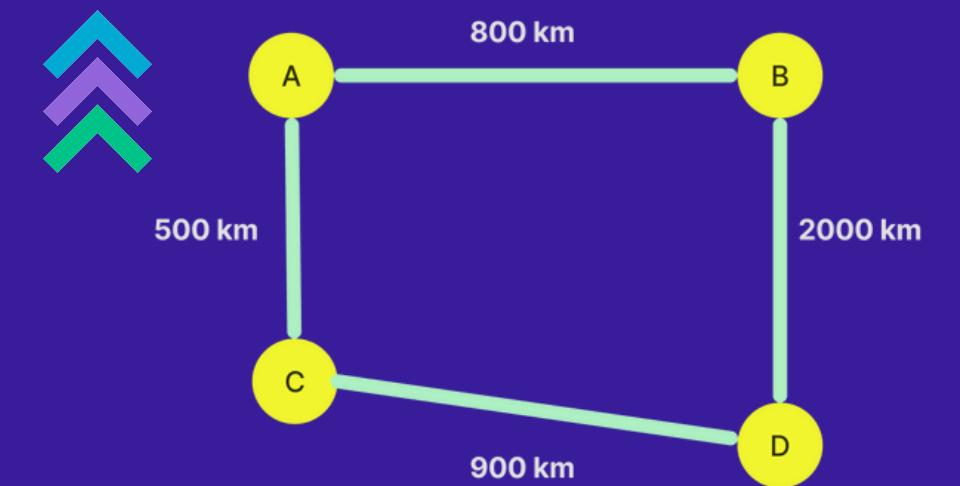
Demand: 100 Gbps  
Priority: 100 Gbps  
200 Gbps  
300 Gbps  
500 Gbps  
400 Gbps

Demand: 400Gbps  
Priority: 400 Gbps  
500 Gbps

# Top-Down Flowchart



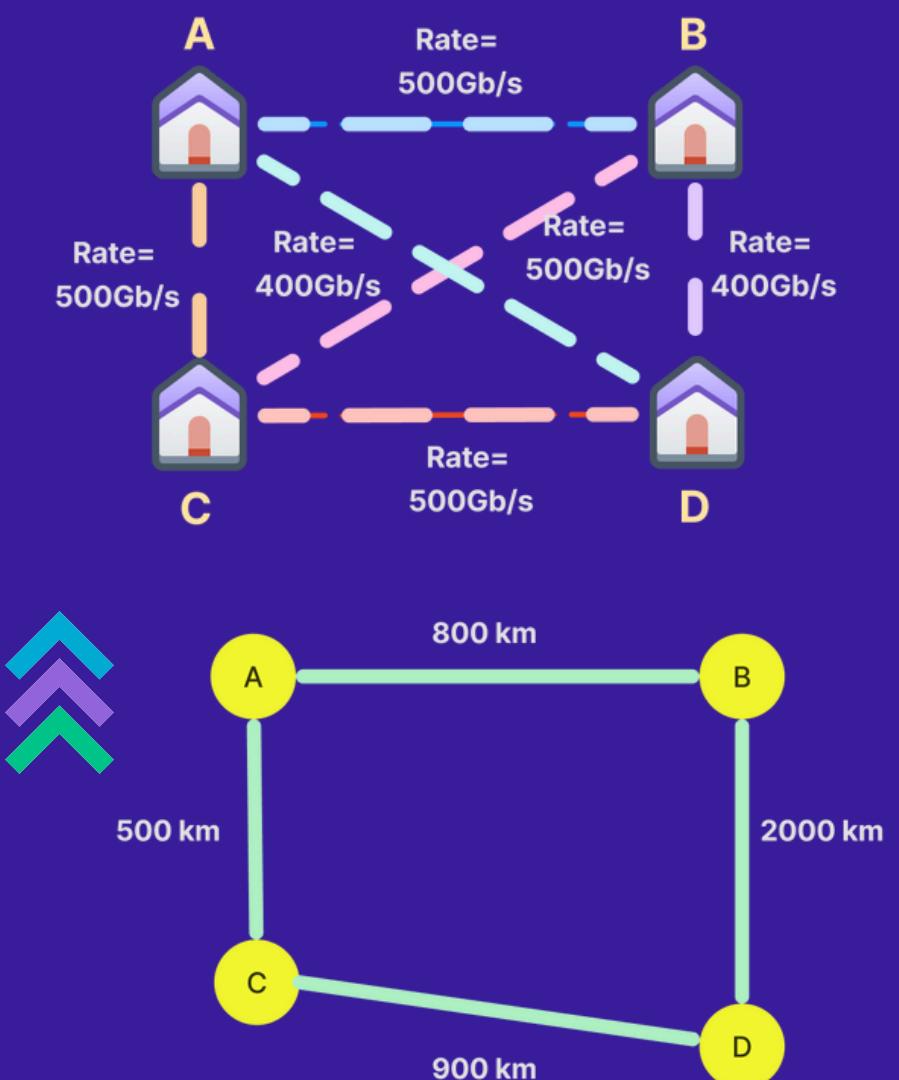
# Approaches examples



Bottom-up

## Approaches examples

Deployment of WDM trails  
based on the K-shortest  
path continues until one link  
reaches the 96-channel  
constraint.

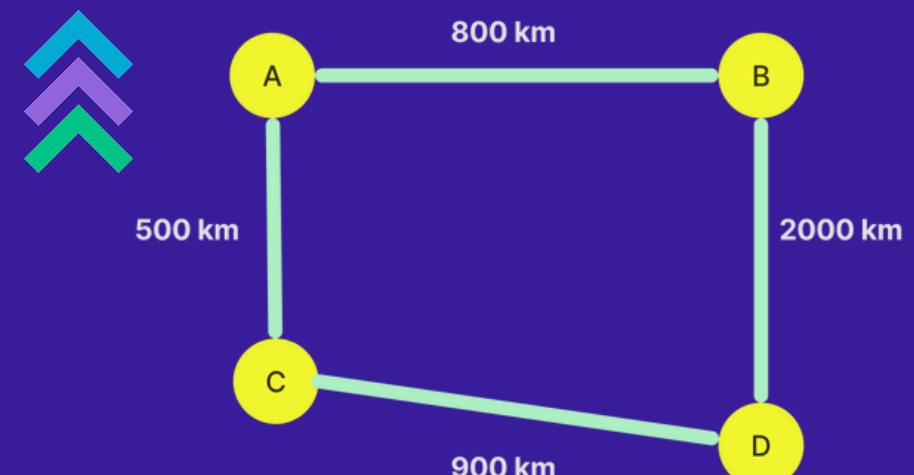
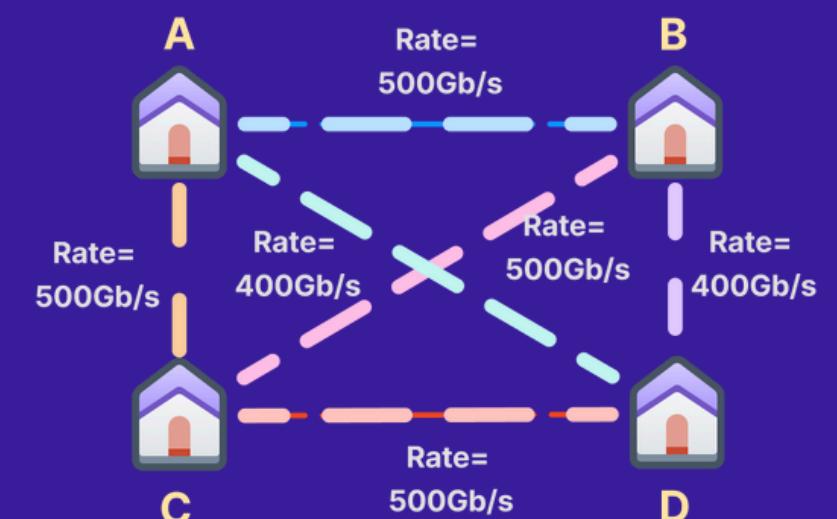
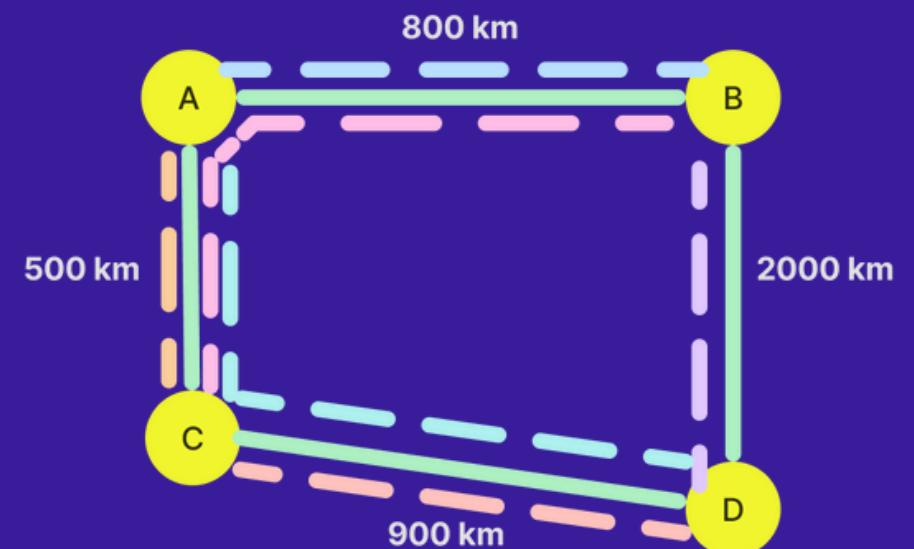


Bottom-up

## Approaches examples

**After the deployment of WDM trails,  
we start routing the demands:**

Deployment of WDM trails  
based on the K-shortest  
path continues until one link  
reaches the 96-channel  
constraint.



**Bottom-up**

# Approaches examples

After the deployment of WDM trails, we start routing the demands:

D1: A  $\rightarrow$  D 100 Gbps

WDM trail(A,D): A-C-D

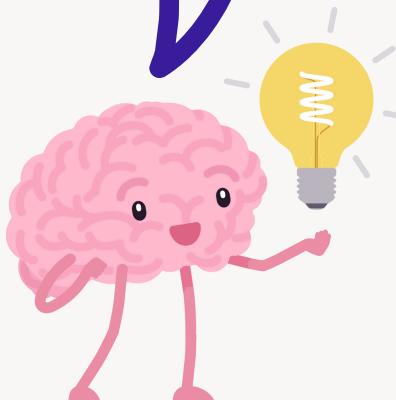
D2: C  $\rightarrow$  D 400 Gbps

WDM trail(C,D): C-D

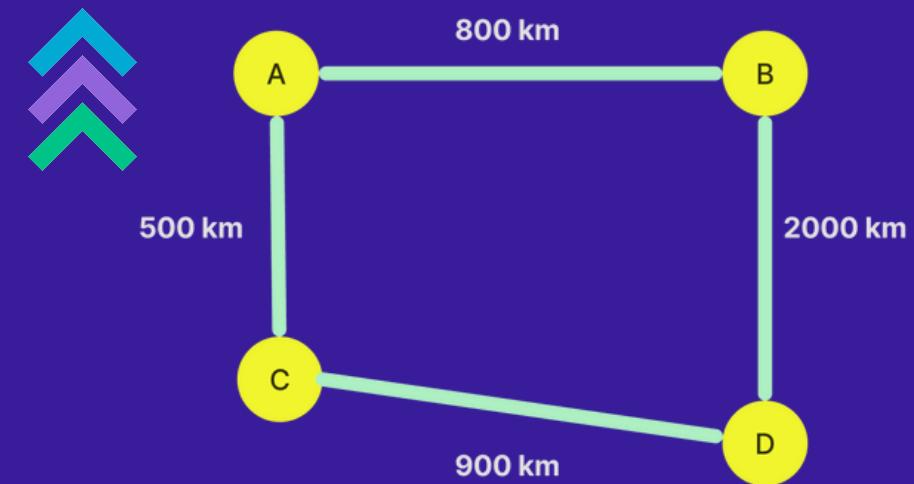
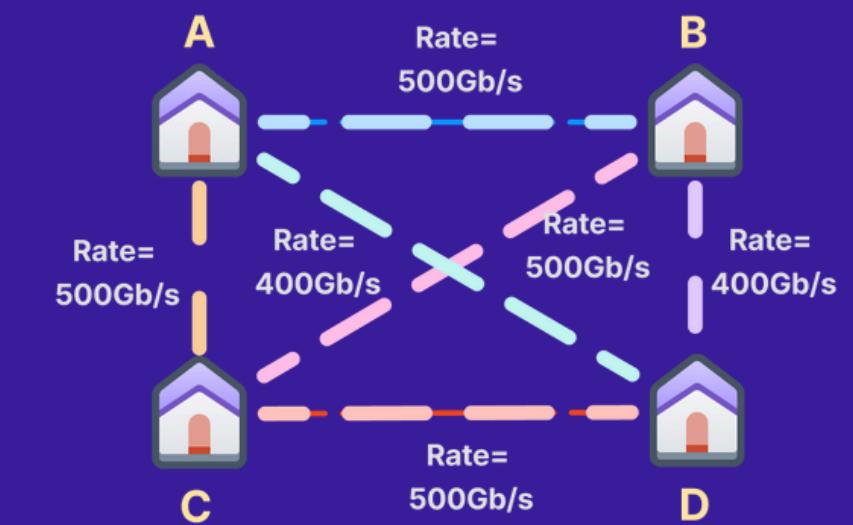
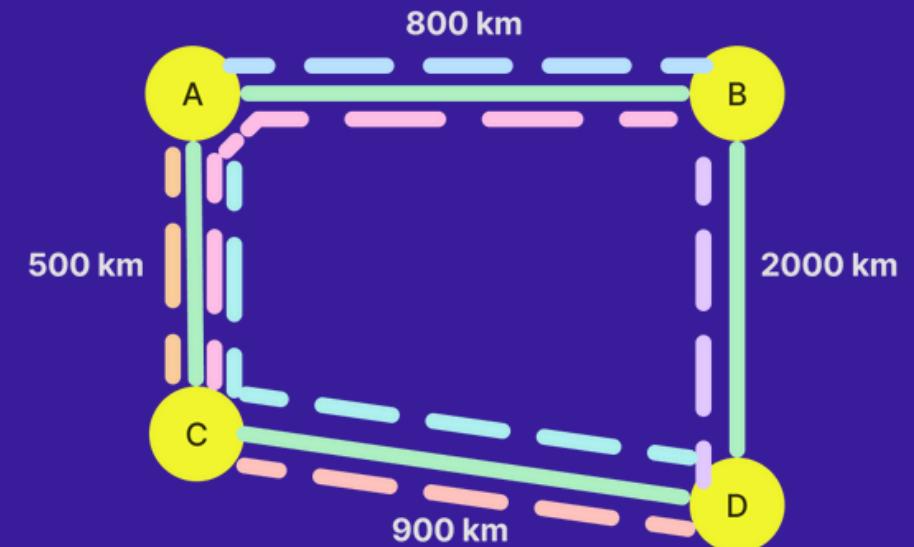
## Grooming

Based on demands table  
We groom the ones with same S & D and data rate.

Optimization algorithm  
K- shortest path  
knapsack

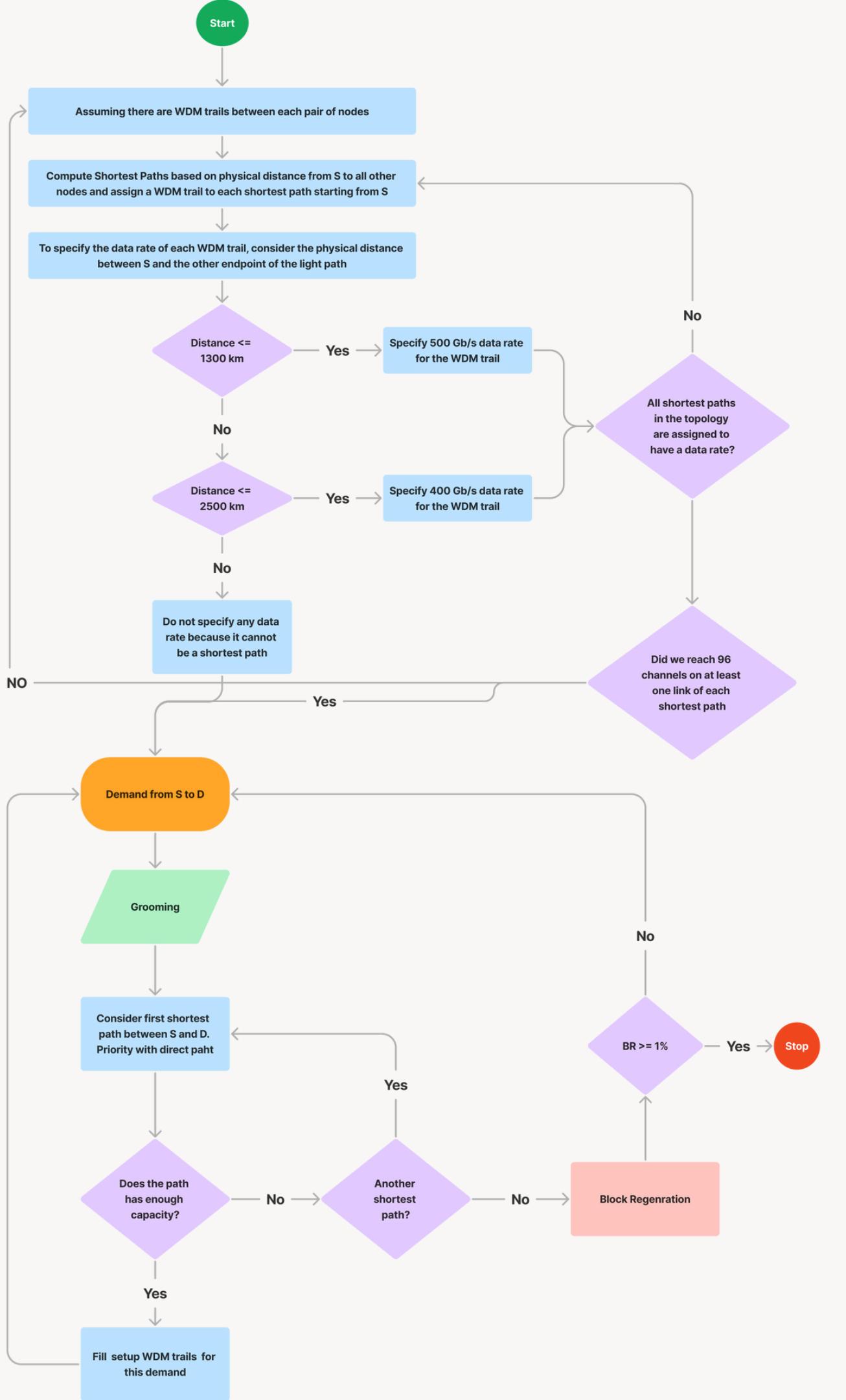


Deployment of WDM trails based on the K-shortest path continues until one link reaches the 96-channel constraint.



Bottom-up

# Bottom-up flowchart



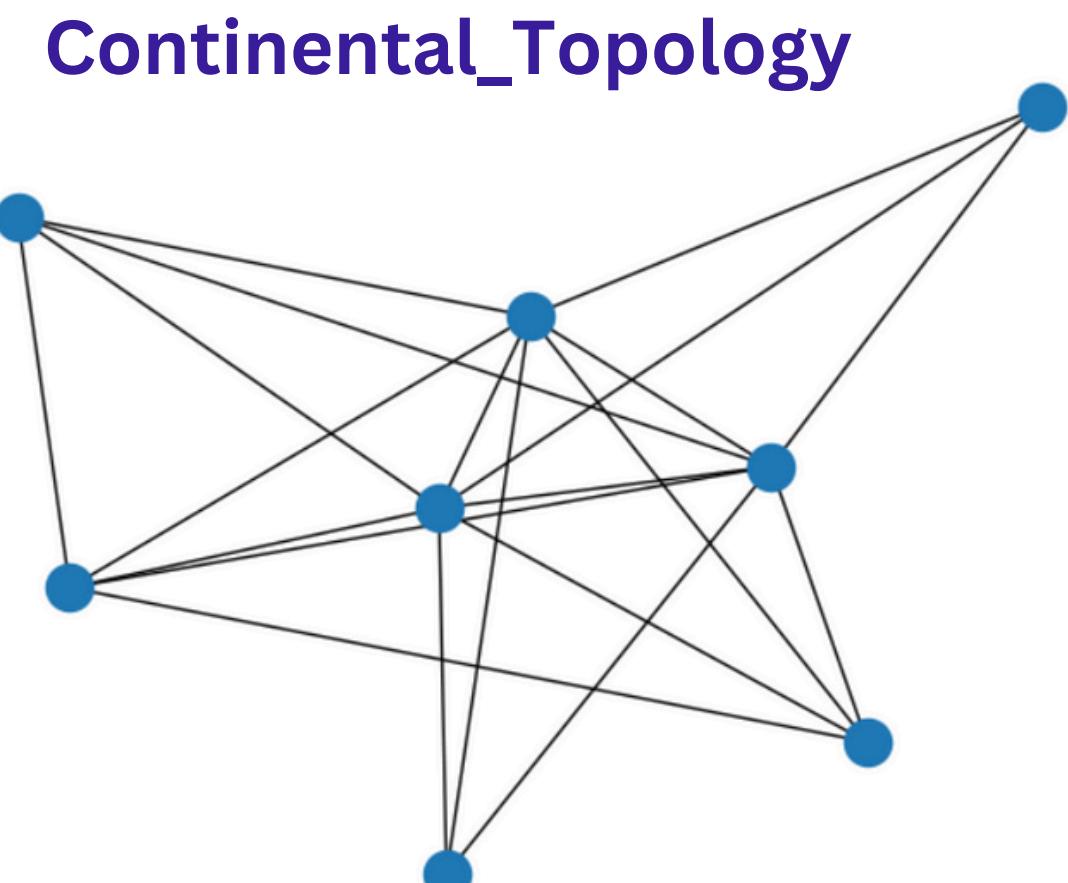
Problem statement

Step 2  
Approaches and examples

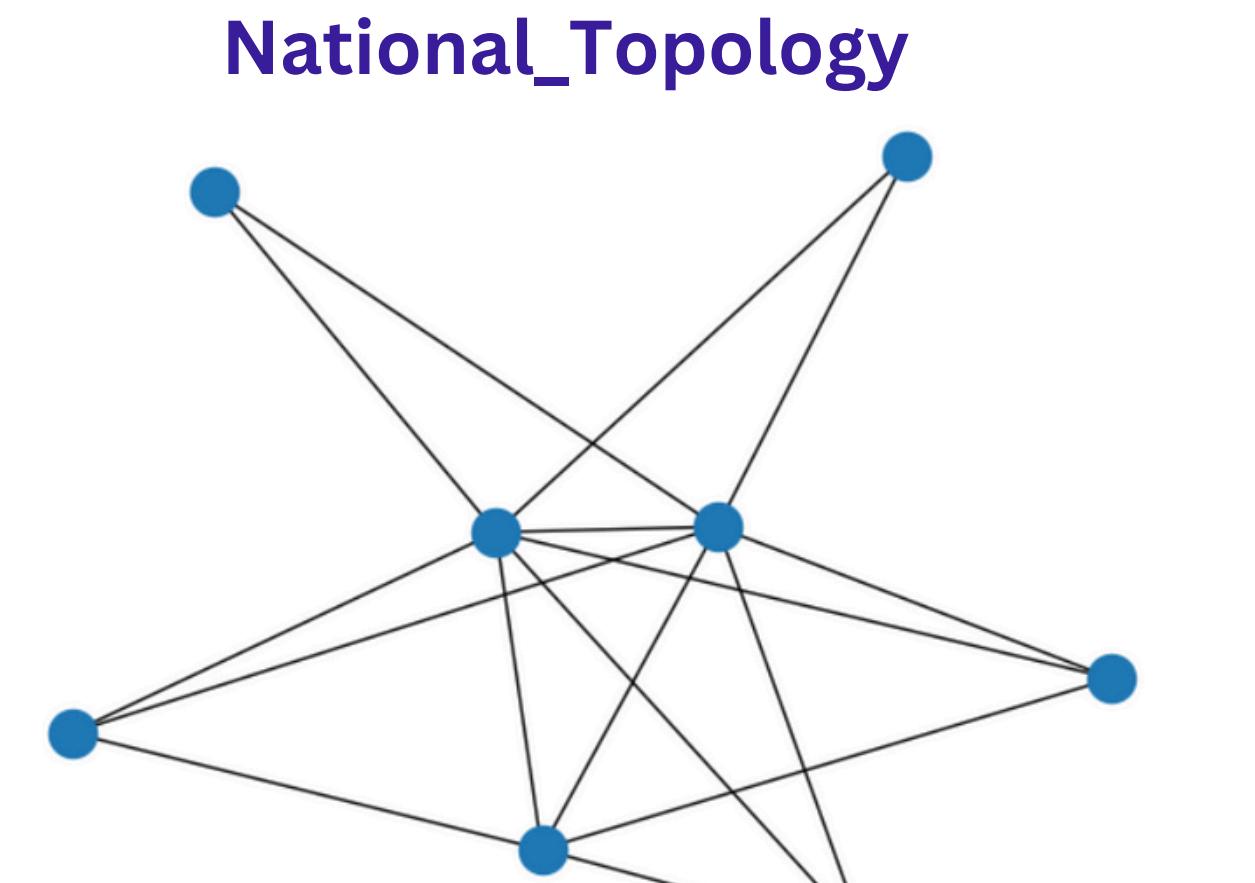
## Simulation

Step 4  
Comparison

Step 5  
Conclusion



# links	20
# Nodes	8
Average	456
Max Link	1000



# links	16
# Nodes	8
Average	167
Max Link	400

Problem statement

Step 2

Approaches and examples

Step 3

Simulation

## Comparison

Step 5

Conclusion

**Filling ratio**

**Measures how efficiently the capacity of the WDM trails is utilized.**

**Average fiber occupation**

**refers to the average number of WDM channels (or wavelengths) used in the fibers of the network.**

**Blocking Rate**

**Represents the proportion of service demands that cannot be routed.**

Problem statement

Step 2

Approaches and examples

Step 3

Simulation

Step 5

## Comparison

Conclusion

### Filling ratio

$$Filling\ Ratio = \frac{Used\ Bandwidth}{Total\ Available\ Bandwidth}$$

### Average fiber occupation

$$Average\ Fiber\ Occupation = \frac{Used\ Channels}{Total\ Channels}$$

### Blocking Rate

$$Blocking\ Rate = \frac{Number\ Of\ Blocked\ Demands}{Total\ Number\ Of\ Demands}$$

Problem statement

Step 2

Approaches and examples

Step 3

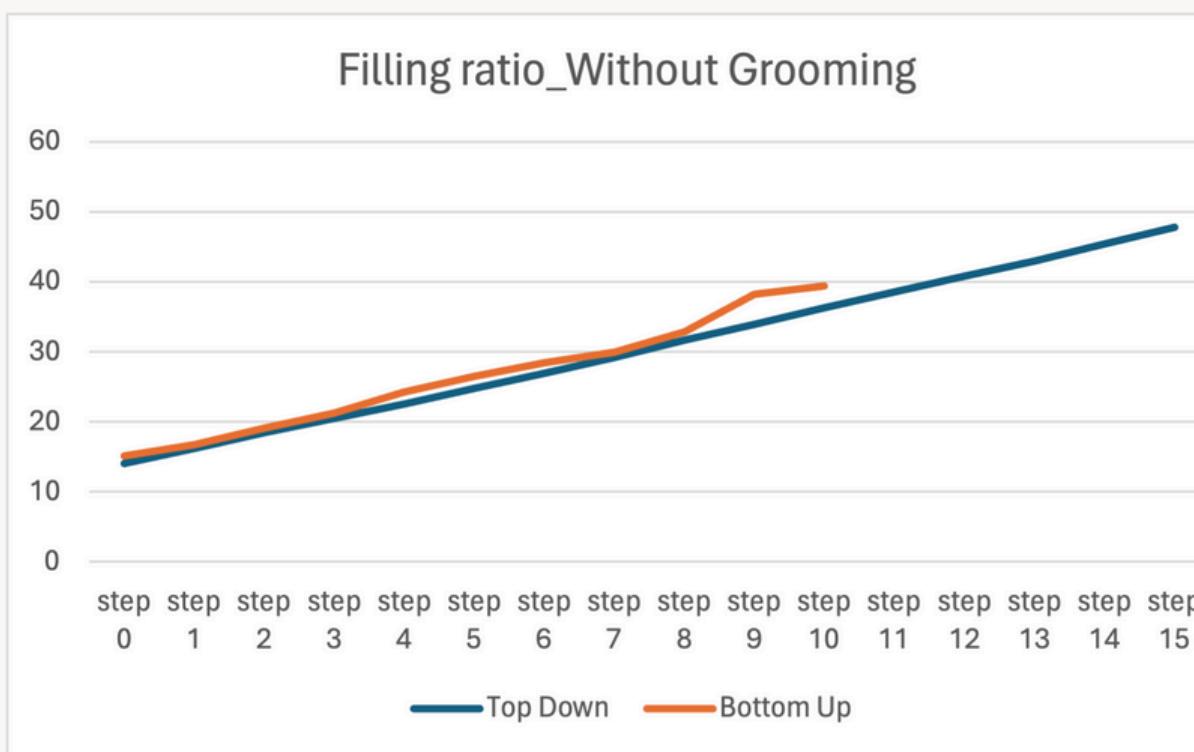
Simulation

Step 5

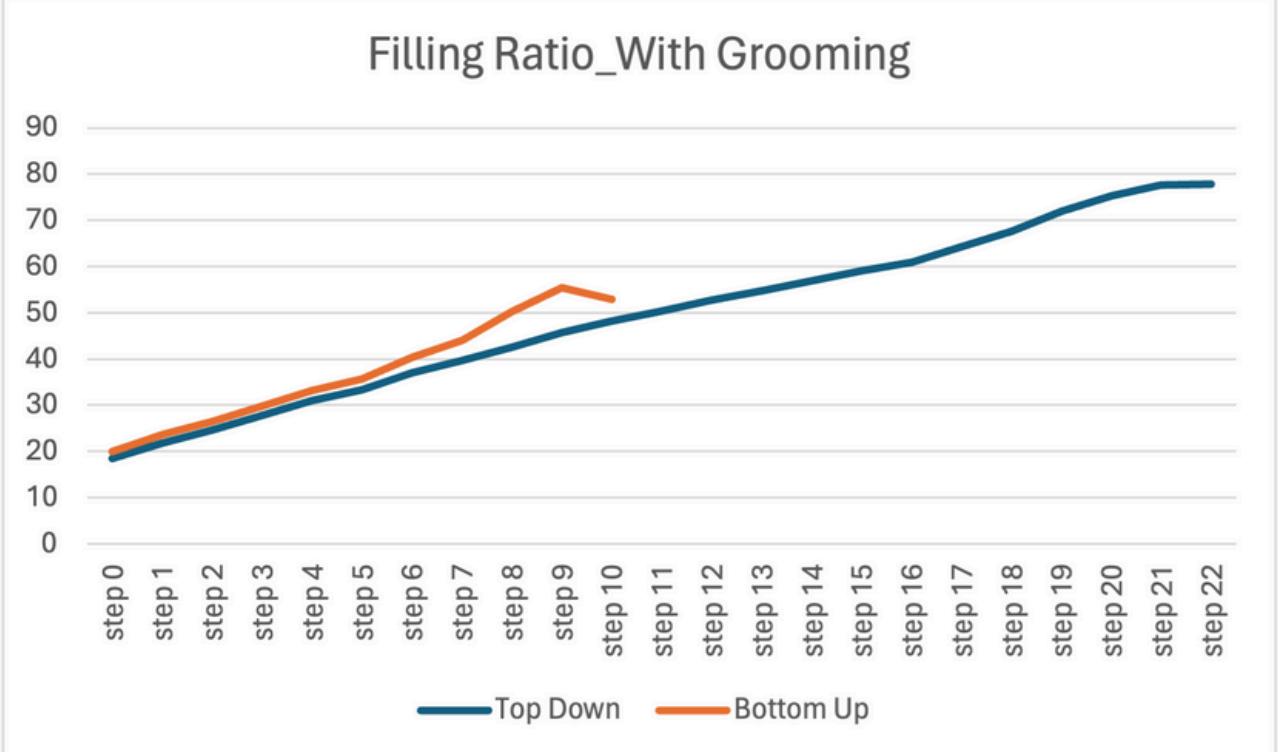
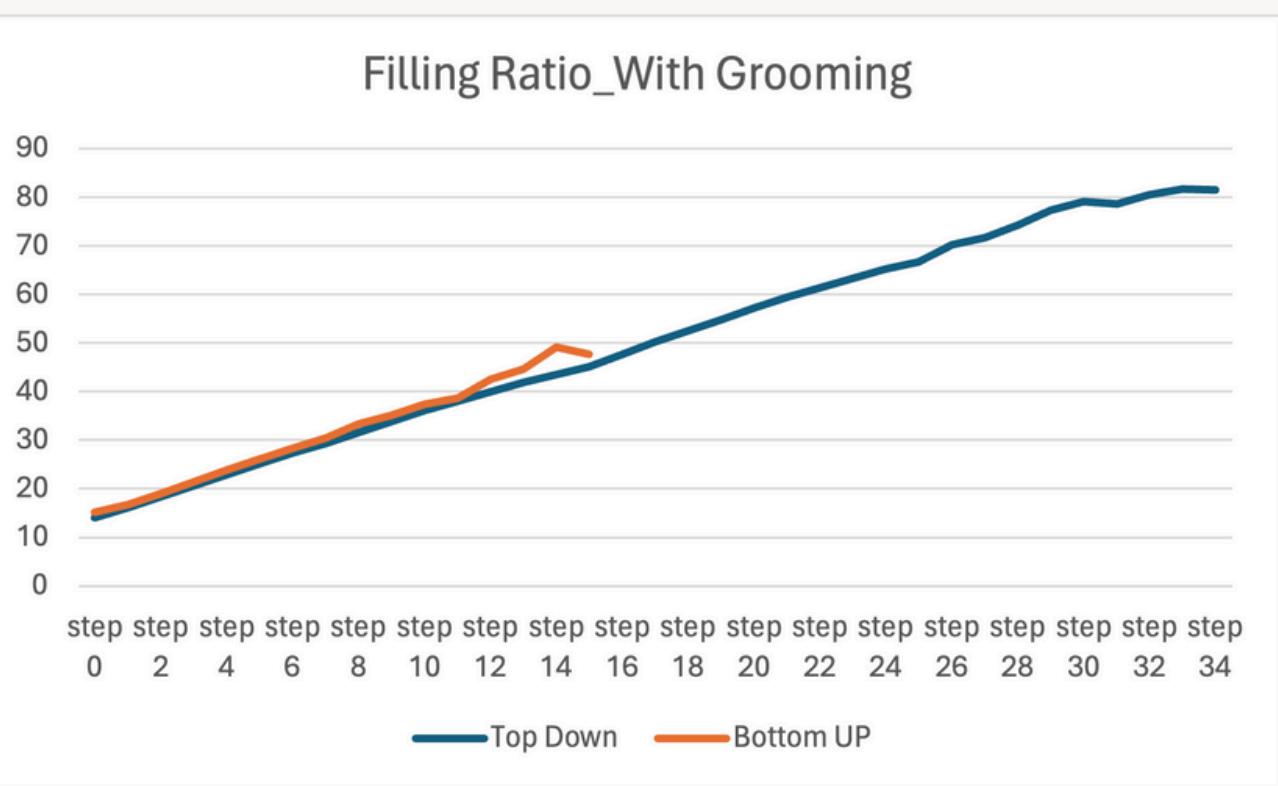
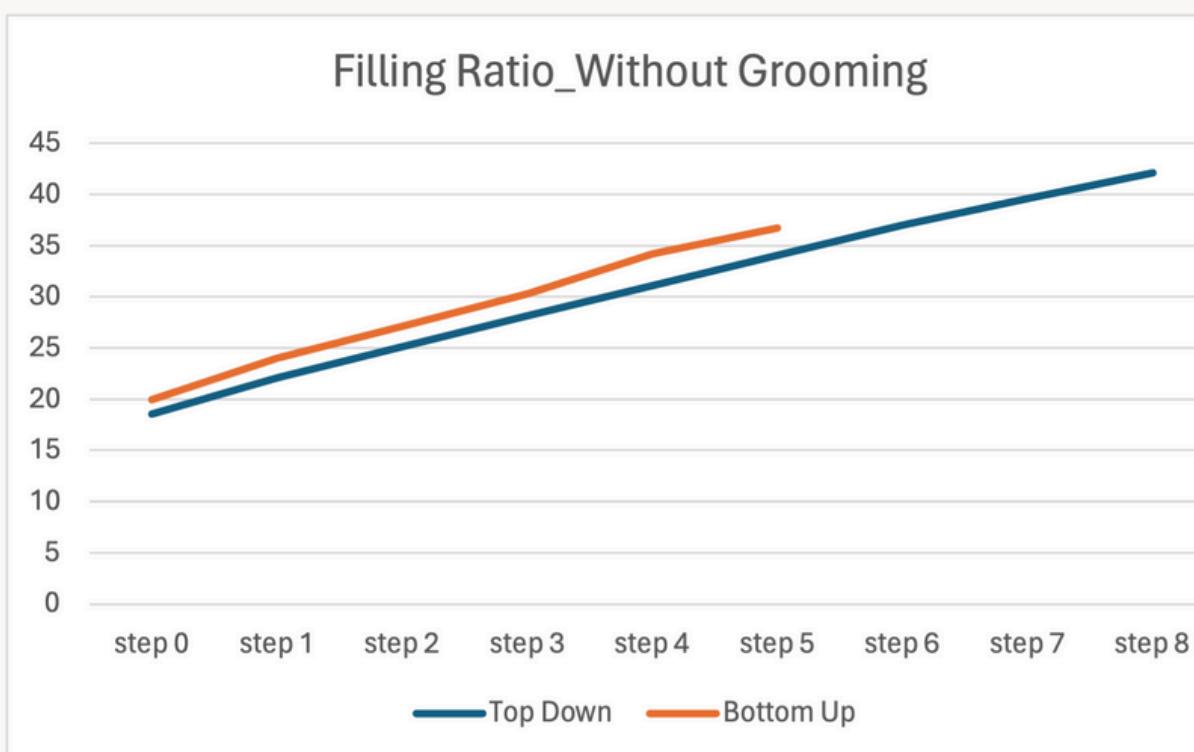
Conclusion

## Comparison

Continental



National



## Problem statement

## Step 2

### Approaches and examples

## Step 3

### Simulation

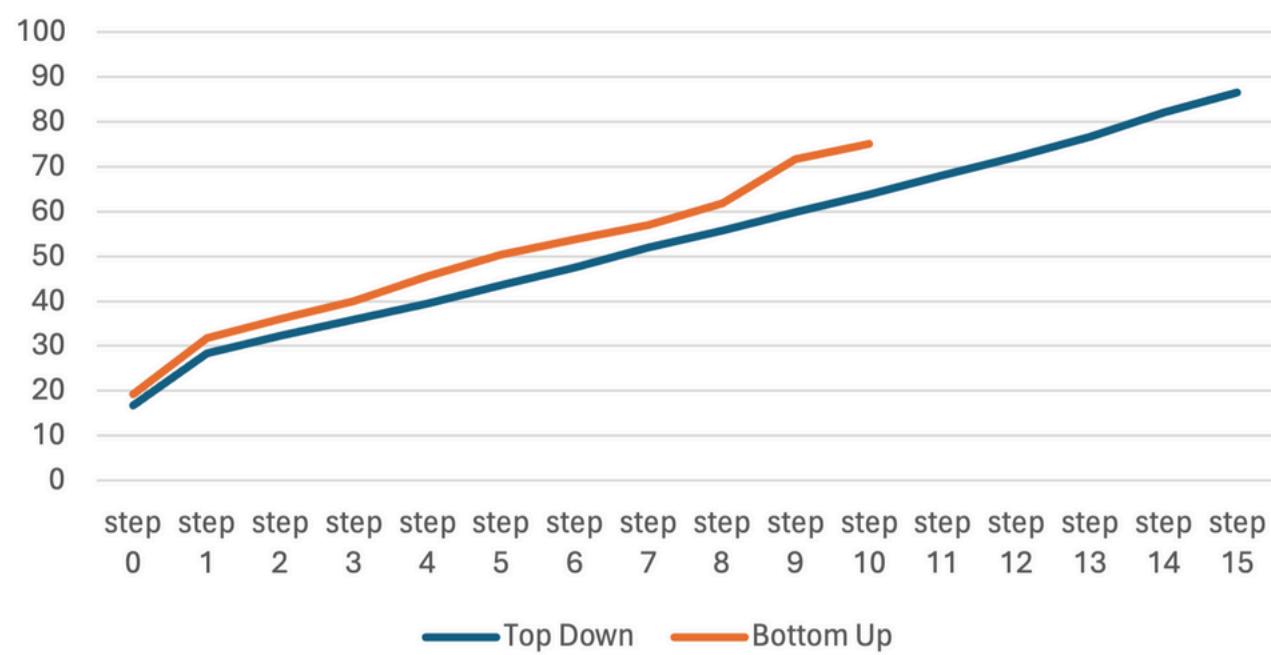
## Step 5

### Conclusion

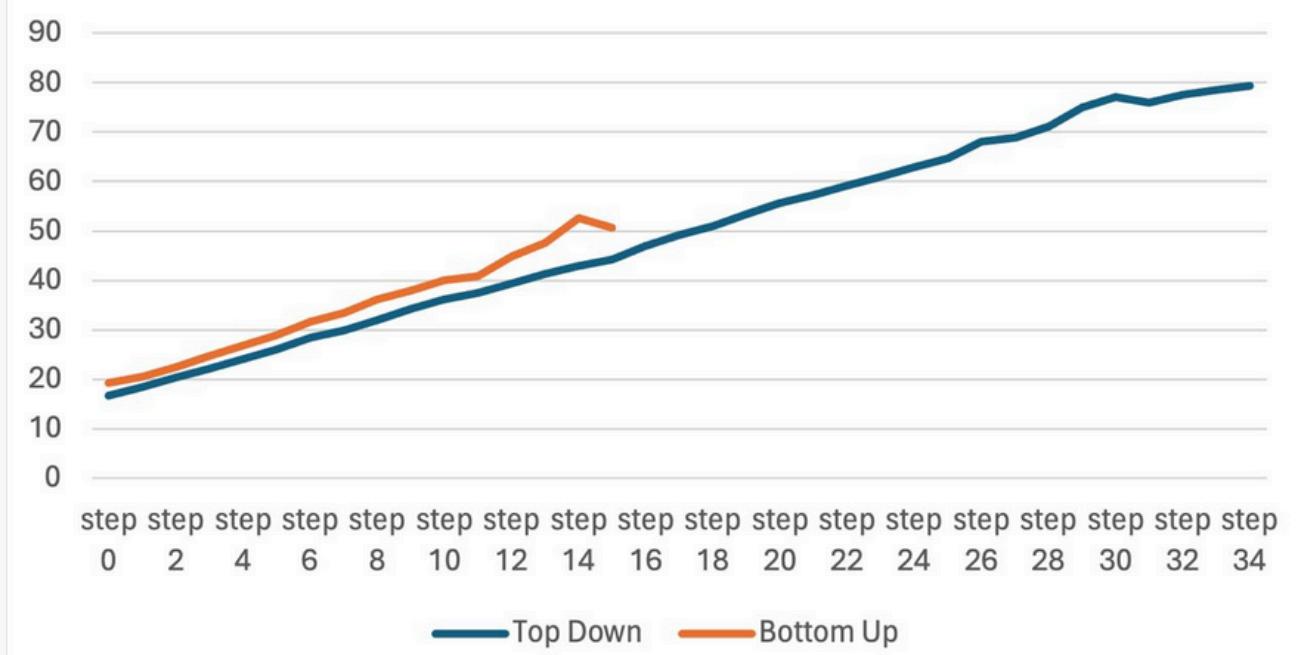
# Comparison

Continental

Average Fiber Occupation\_Without Grooming

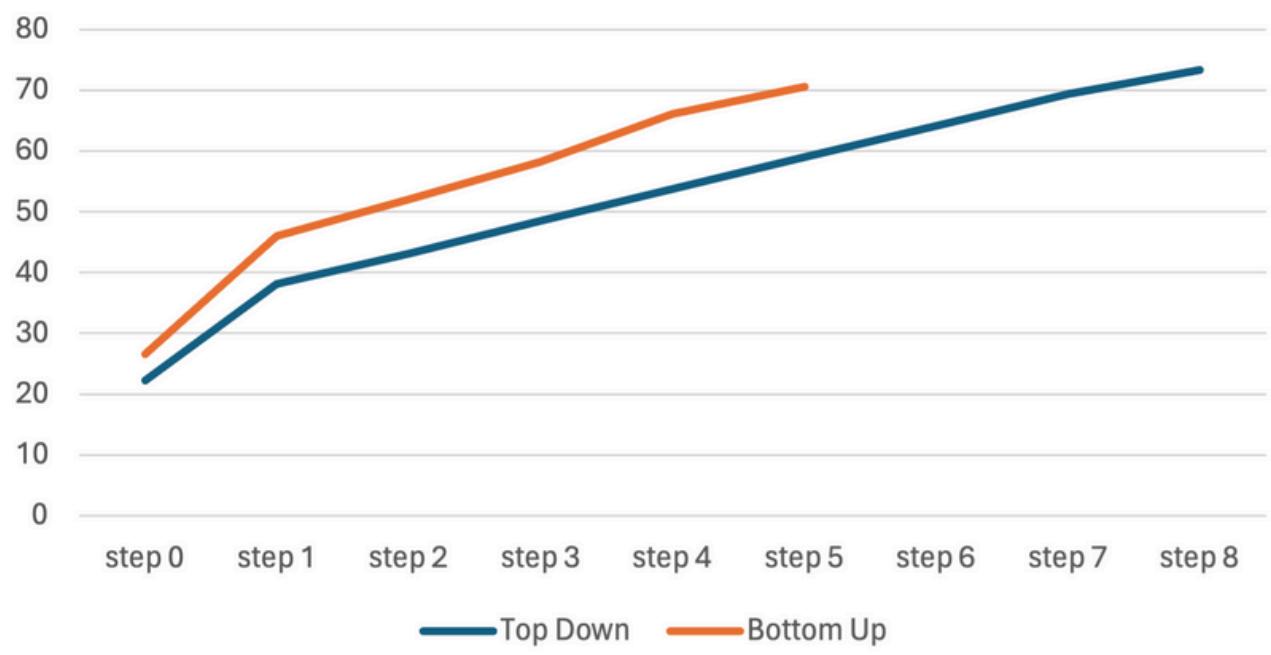


Average Fiber Occupation\_With Grooming

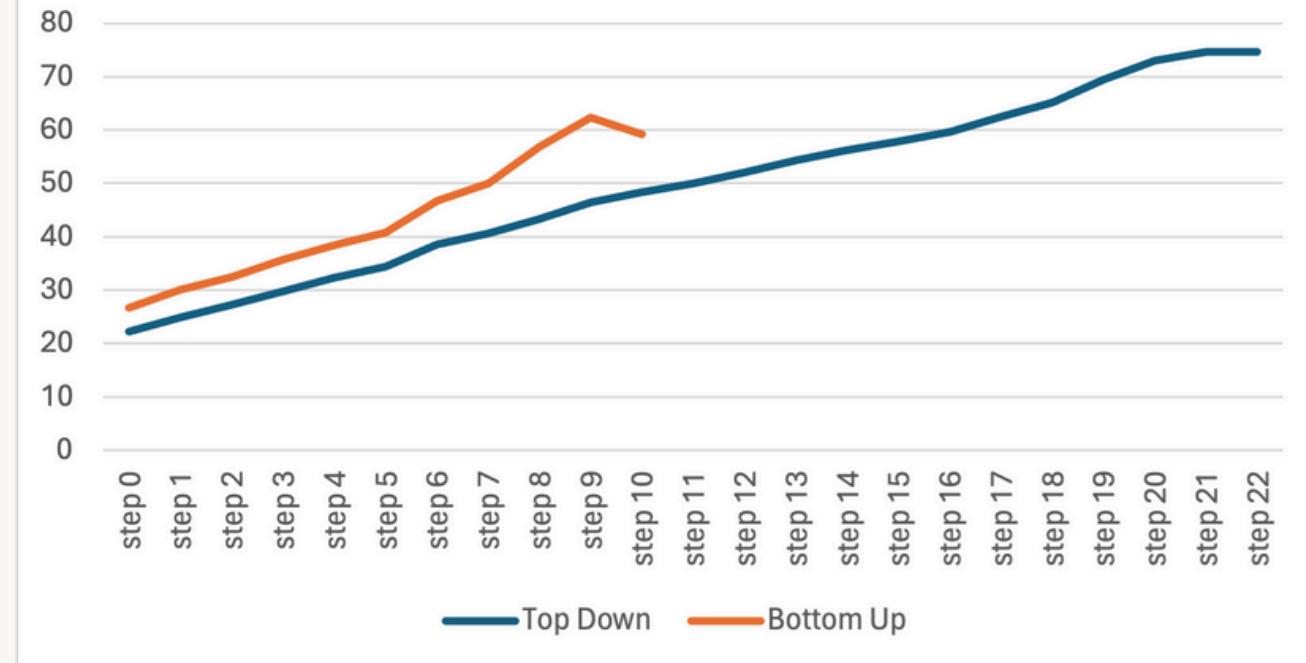


National

Average Fiber Occupation\_Without Grooming



Average Fiber Occupation\_With Grooming



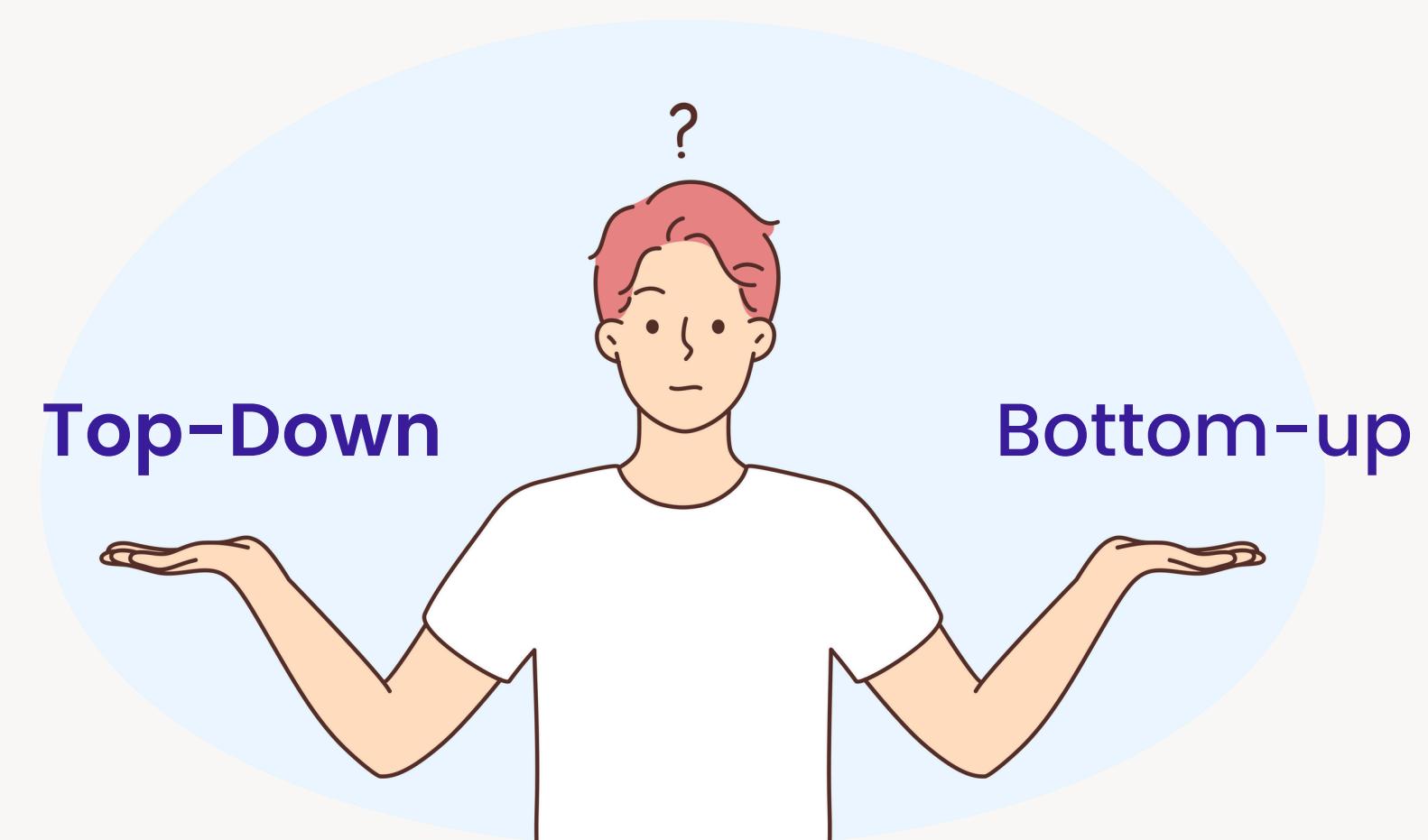
Problem statement

Step 2  
Approaches and  
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Problem statement

Step 2  
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**In nut shell, whenever we need more demands to pass we can go through top down approach as you saw we can have pass more demands and blocking rate happened not sooner as bottom up Contractly, we use bottom up when time is important for us, since in bottom up before looking at demands we create wdms and this may lead to better time response.**

THANK

YOU

