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Multilayer Planning for Facebook Scale Worldwide Network

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A Case Study of the Facebook Backbone

- Multilayer study of the world wide Facebook backbone
- Collaborated with **Aria Networks to use their** genetic algorithm solution

- The approach solves the IP and optical layer together
- It explores solutions beyond shortest paths
- The metaheuristic scales to solve a network with 100+ sites and 200+ links
- Models restoration of low priority services in the optical layer
- Shows savings of 25% in the total cost of network ownership

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Facebook Key Metrics

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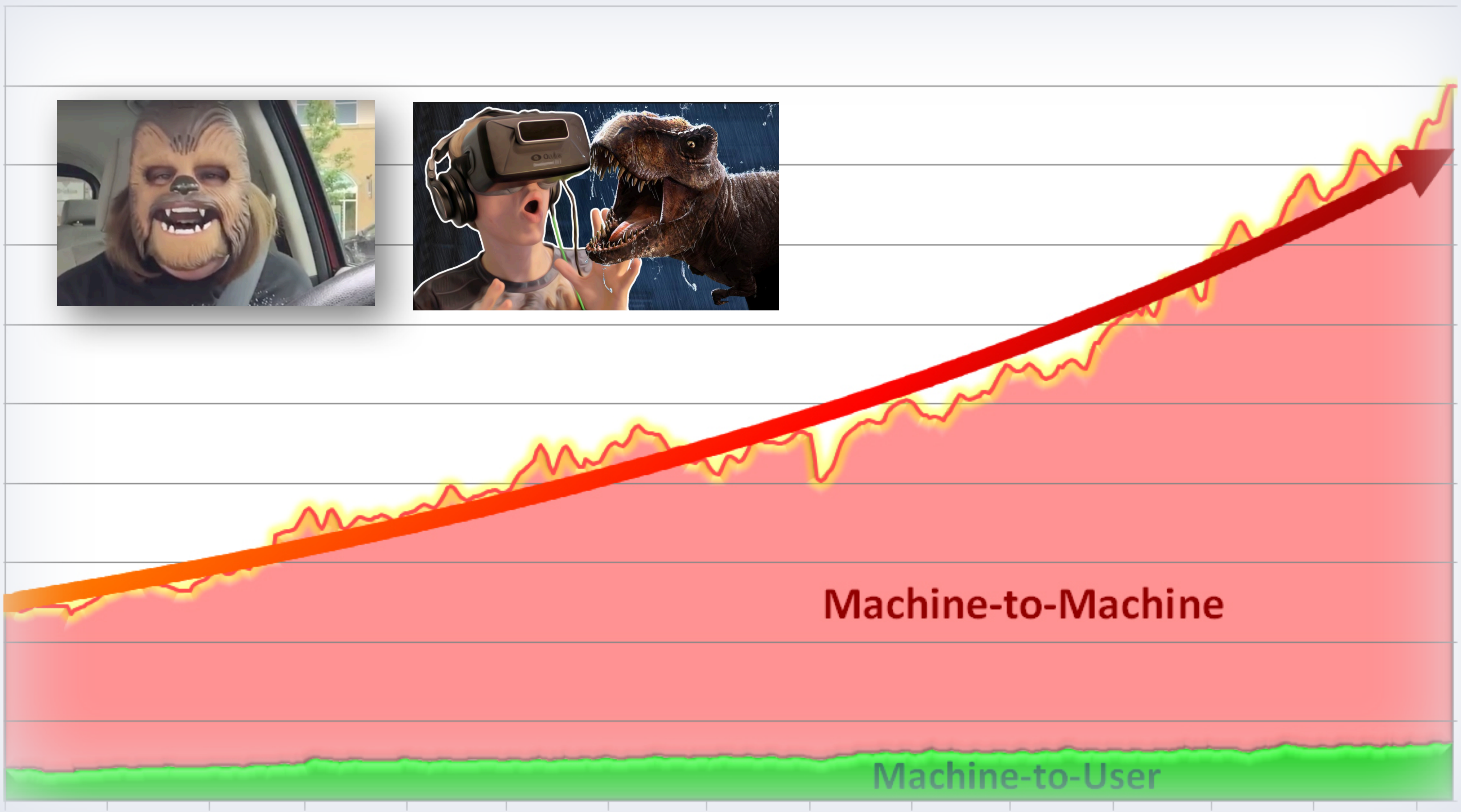
Traffic Demand

Billions of Photos, Videos, and Messages daily



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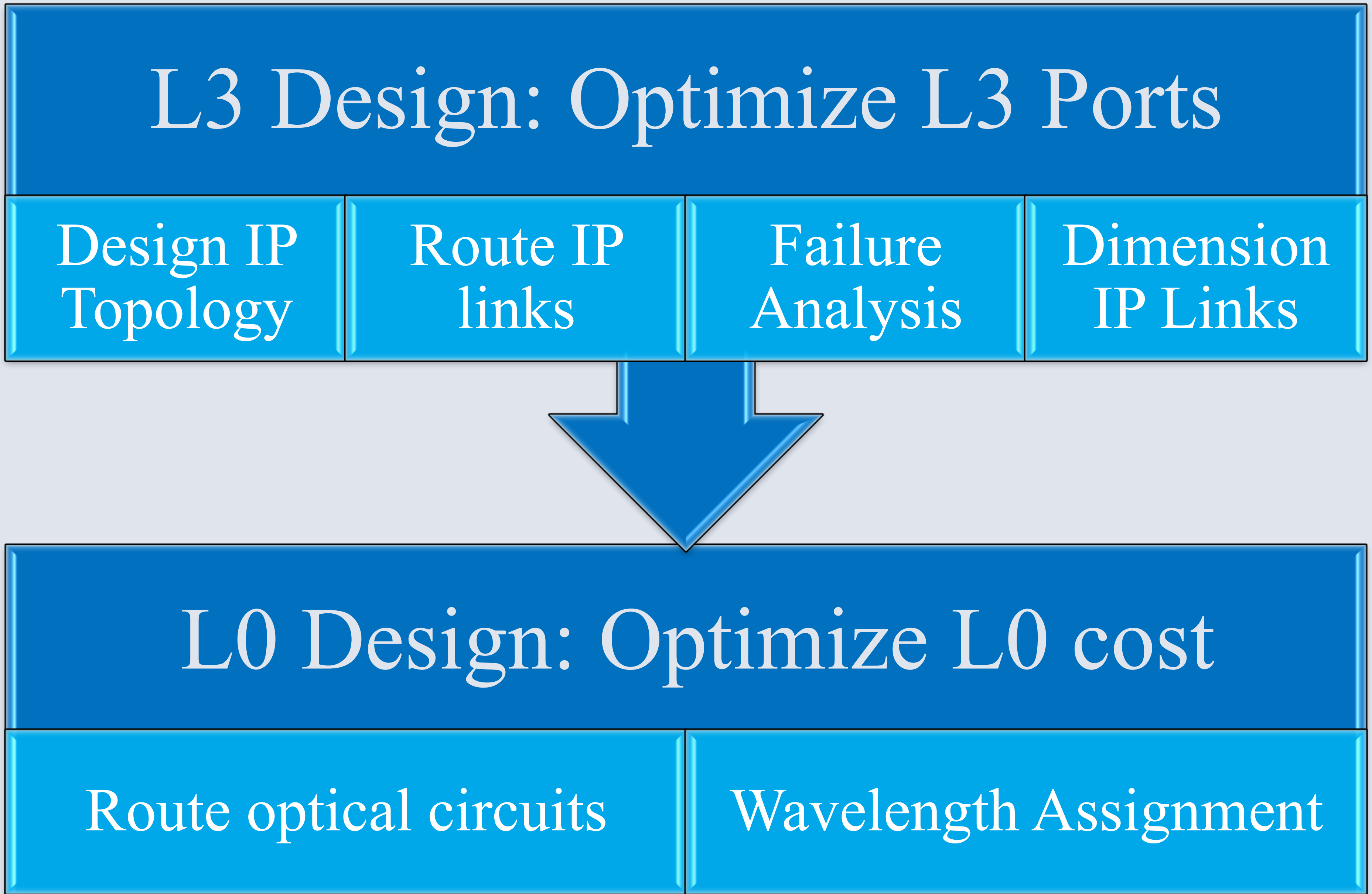
Traditional Network Planning



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Traditional Network Planning

Multilayer Planning

Multilayer Design: Optimize Total Cost of Network Ownership

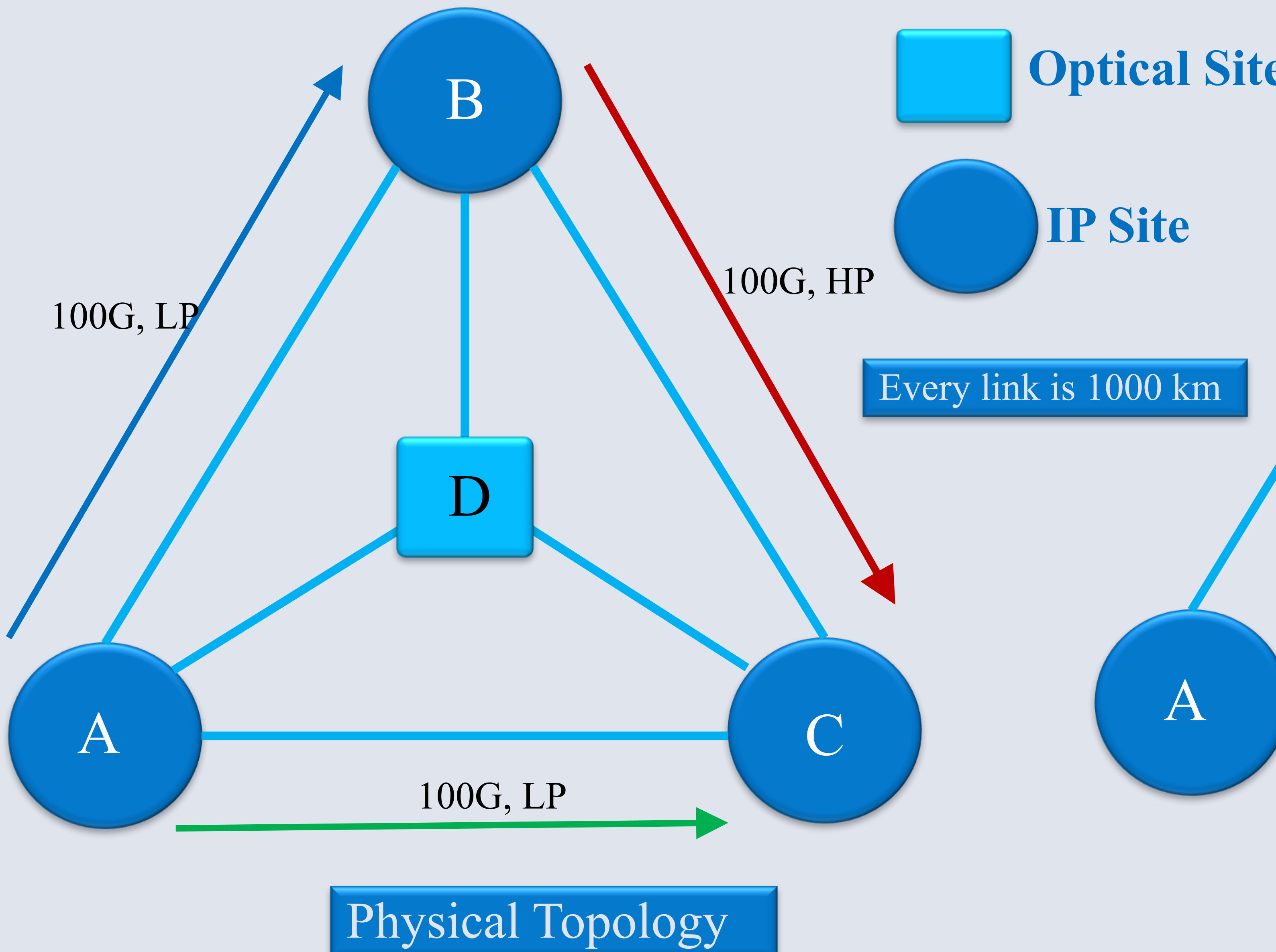
- Design IP Topology
- Route IP links
- Failure Analysis
- Route Optical Circuits
- Wavelength Assignment

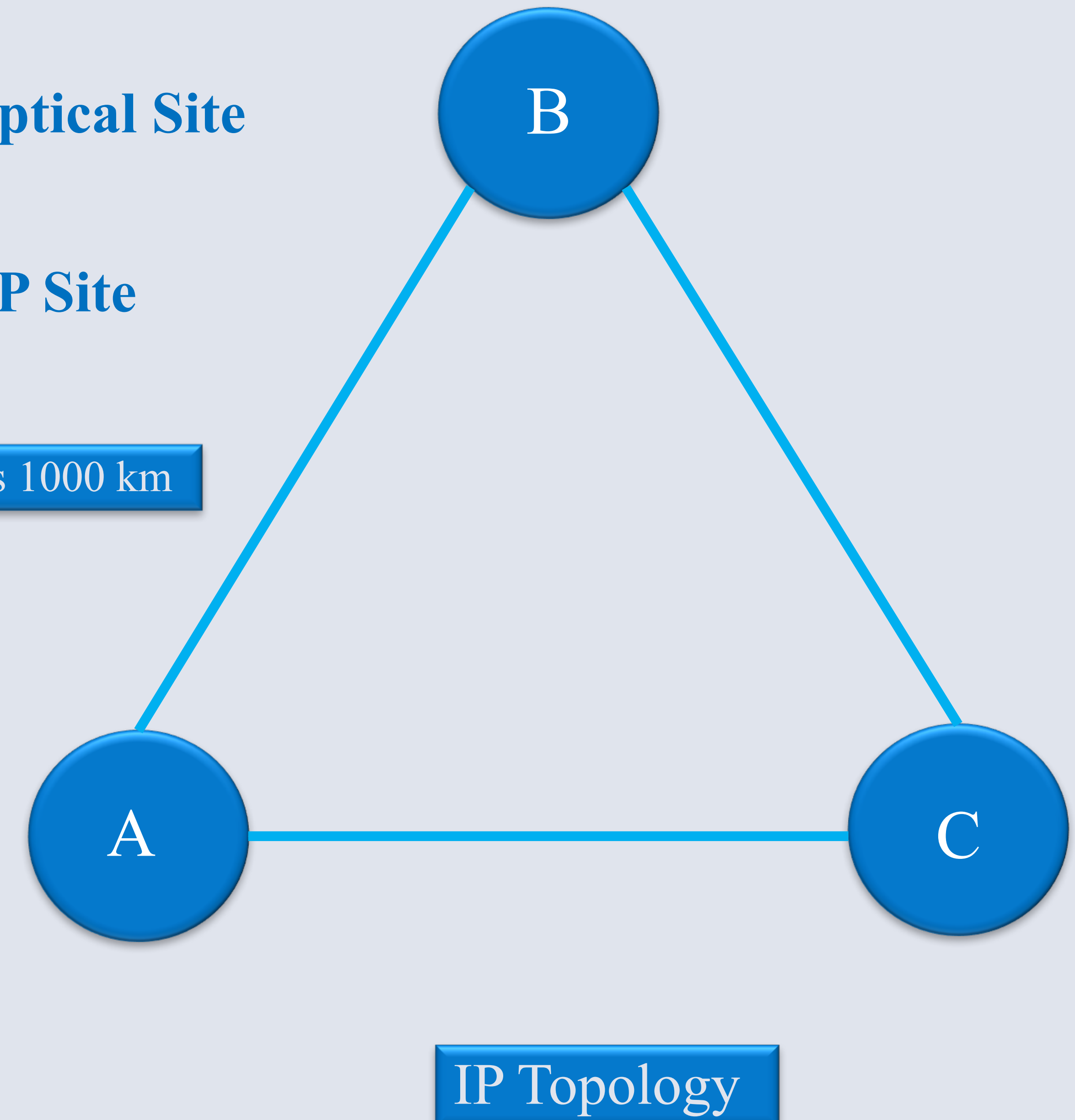
Network Resilience

L3	• IP LFA/FRR
L2.5	• MPLS FRR
L1	• 1+1 Protection
L0	• Restoration

?

Example: A Three Node Network





Scenario Assumptions

- 1000 Km optical reach
- Single fiber failure recovery
- IP port costs 1 unit
- Optical port costs 4 units

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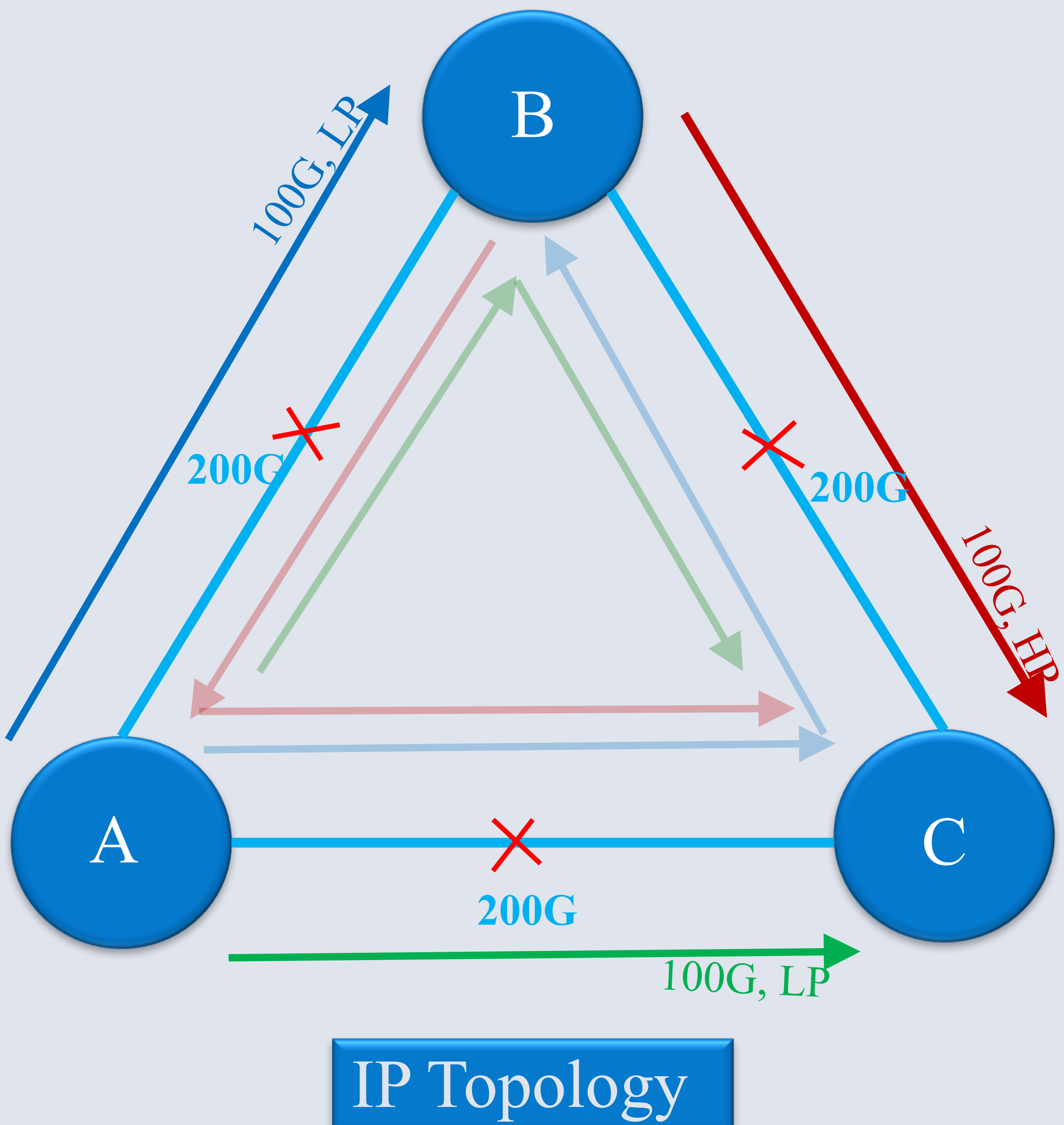
L3 Protection (L3P)



Name	L3	L0	IP Ports	Optical Ports	Regen Ports	Cost	Fibers	Qos
L3P	P	U	12	12	0	60	3	Y

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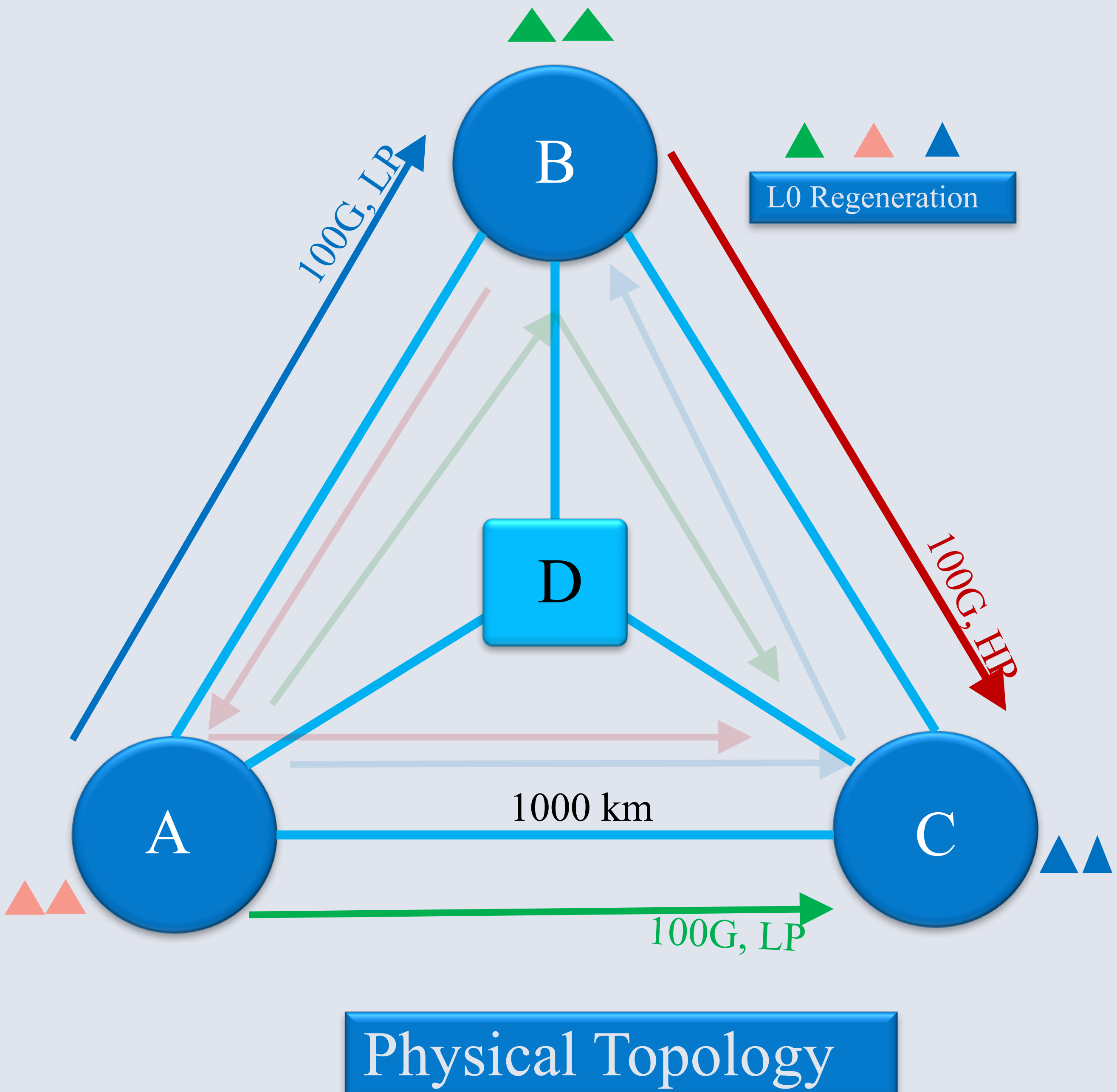
L1 Protection (1+1 L1P)



Name	L3	L0	IP Ports	Optical Ports	Regen Ports	Cost	Fibers	Qos
L3P	P	U	12	12	0	60	3	Y
L1P	**U**	**1+1**	**6**	**12**	**6**	**78**	**3**	**Y**

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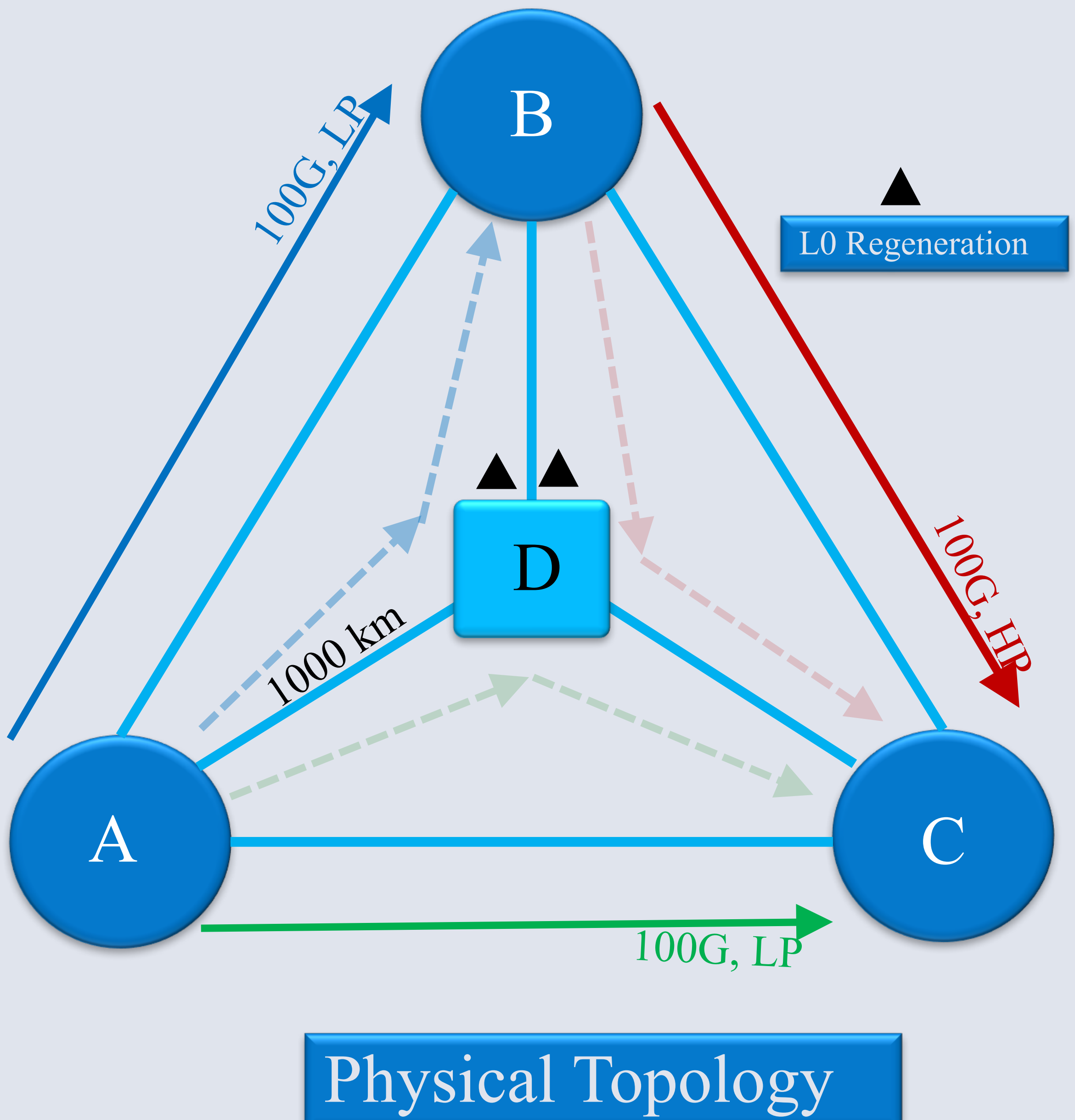
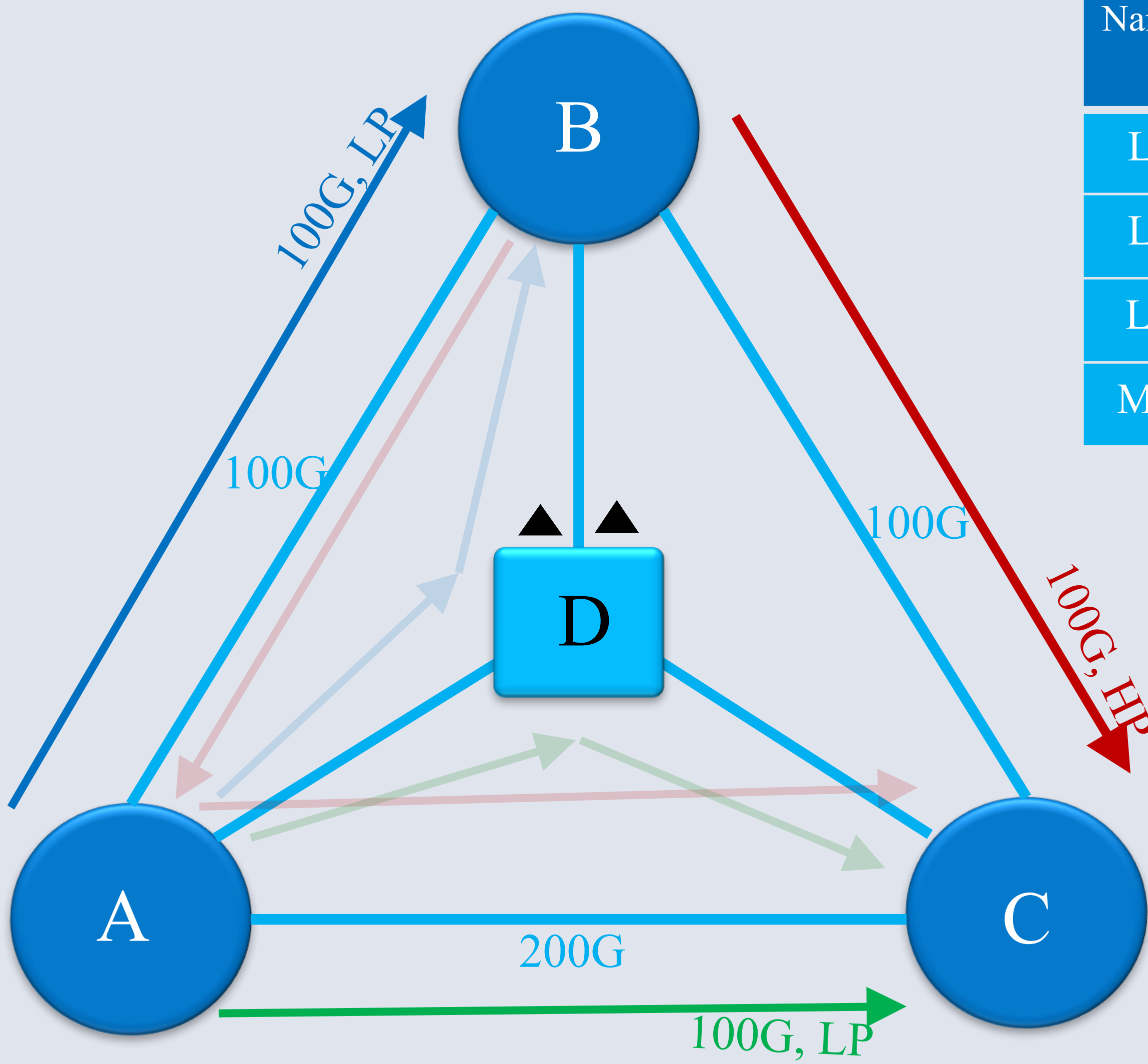
L0 Restoration (L0R)



Name	L3	L0	IP Ports	Optical Ports	Regen Ports	Cost	Fibers	Qos
L3P	P	U	12	12	0	60	3	Y
L1P	**U**	**1+1**	**6**	**12**	**6**	**78**	**3**	**Y**
L0R	**U**	**R**	**6**	**6**	**2**	**32**	**6**	**N**

Multilayer Design (MLR)



Physical Topology

Name	L3	L0	IP Ports	Optical Ports	Regen Ports	Cost	Fibers	Qos
L3P	P	U	12	12	0	60	3	Y
L1P	**U**	**1+1**	**6**	**12**	**6**	**78**	**3**	**Y**
L0R	**U**	**R**	**6**	**6**	**2**	**32**	**6**	**N**
MLR	**HP-P**	**LP-R**	**8**	**8**	**2**	**48**	**5**	**Y**

Lowest cost design that meets QoS

Problem Statement

Input

- Nodes
  - IP Sites
  - Optical Sites
- Links
  - Fibers
- Failure Scenarios
- Latency Constraints
- Costs
  - Port Costs
  - Fiber Costs

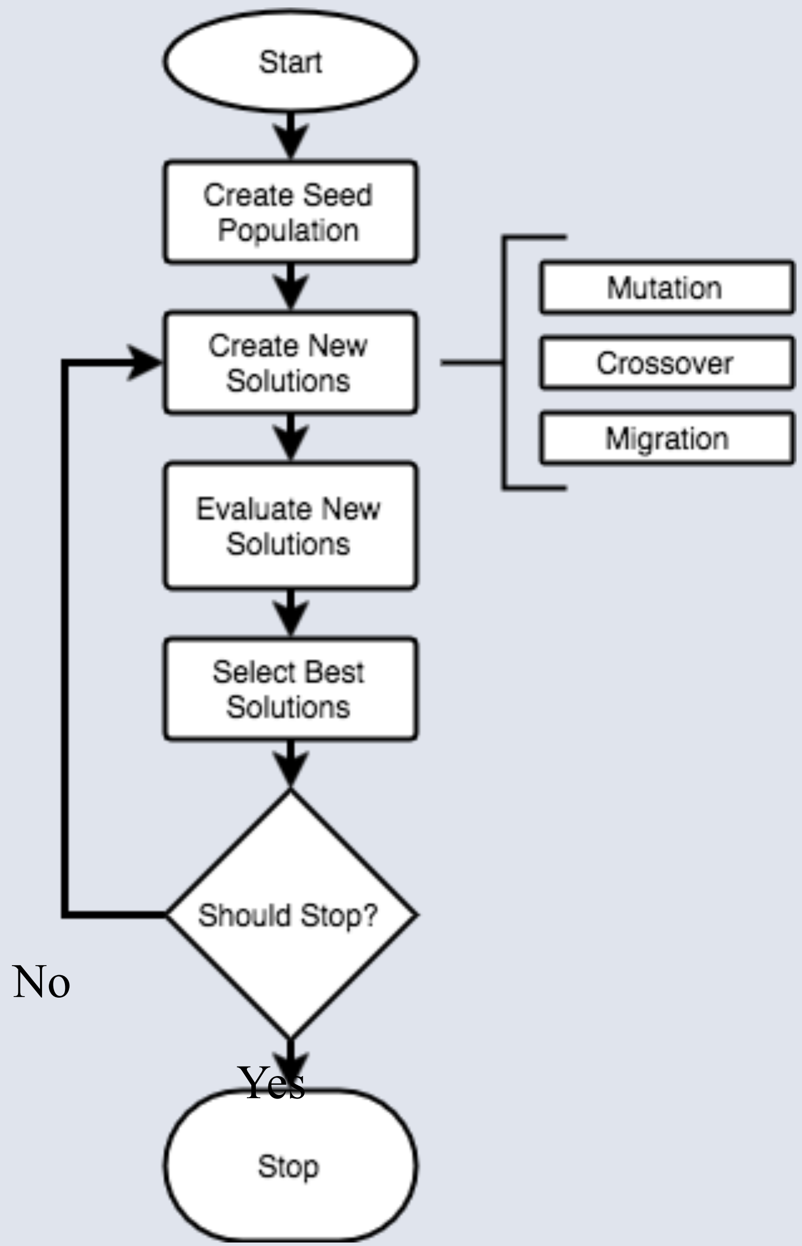
Output

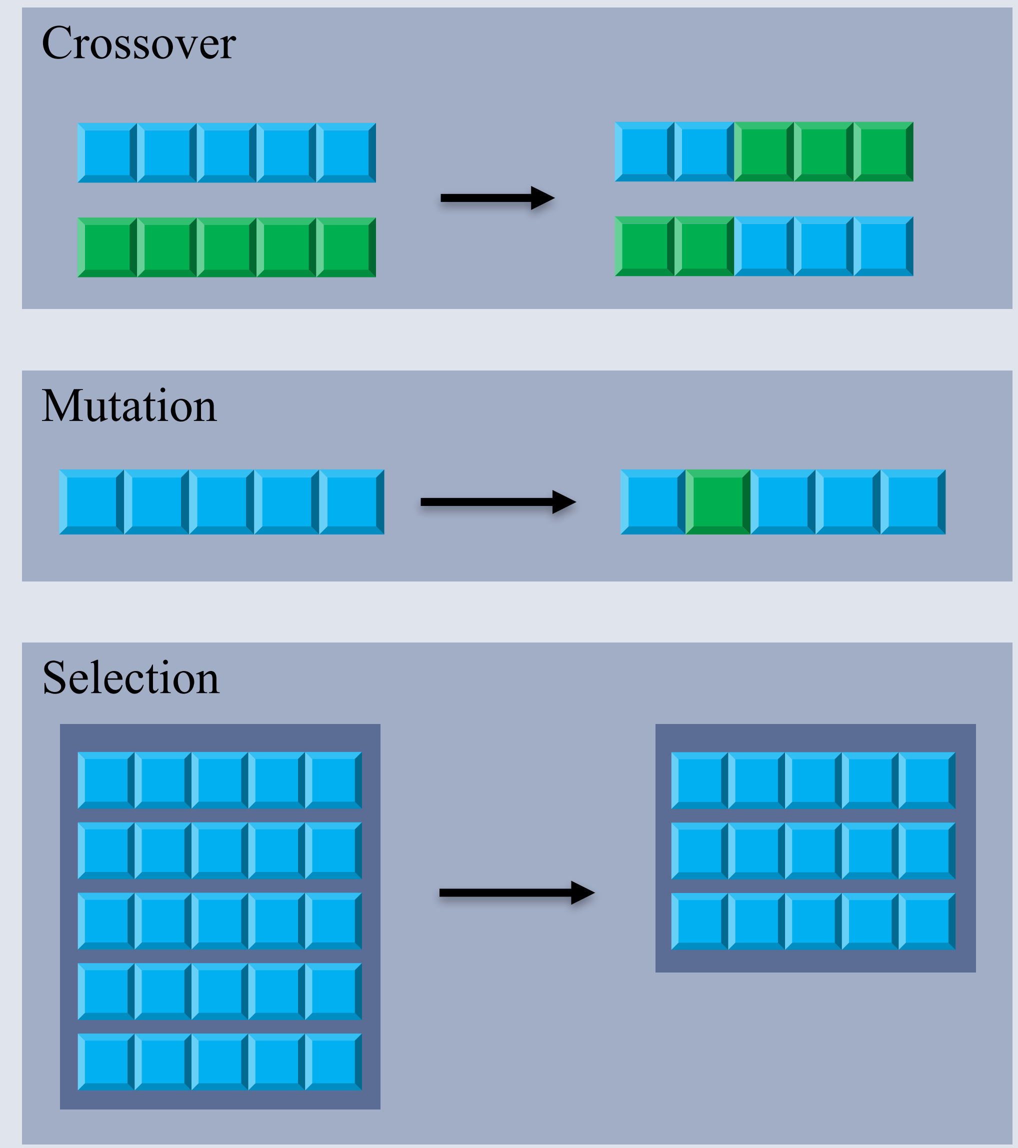
- Virtual Topology Design
  - IP routing
  - IP dimensioning
- Physical Topology Design
  - Optical routing
  - Optical Dimensioning

Objective

- Network Total Cost of Ownership

Genetic Algorithm Approach





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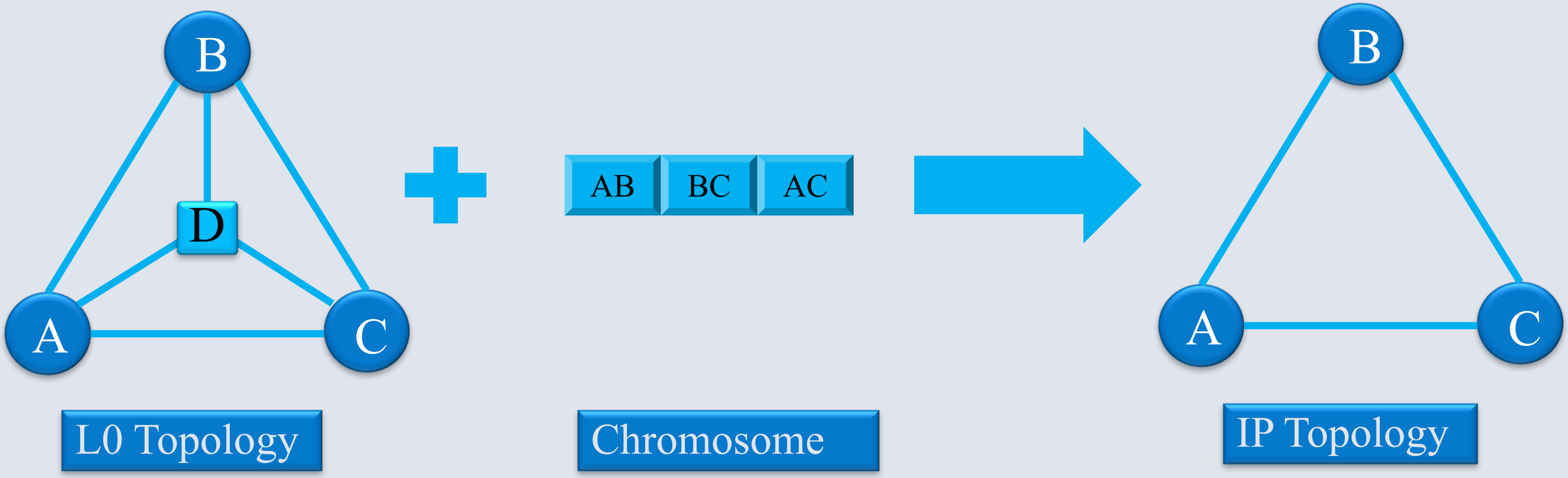
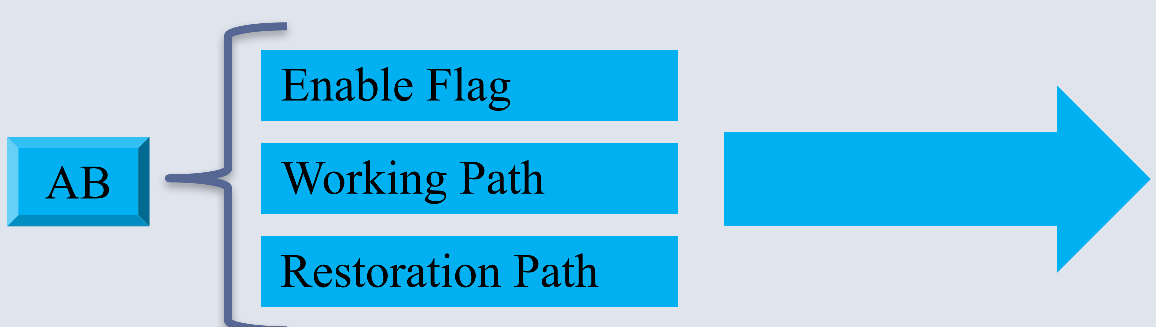
IP Topology Chromosome Representation





AB	BC	AC
True	True	True
[A,B]	[B,C]	[A,C]
[A,D,B]	[B,D,C]	[A,D,C]

GA Operations

Crossover

S1 IP1: <W1, P1> IP2: <W2, P2>

S2 IP1: <W3, P3> IP2: <W4, P4>

S3 IP1: <W1, P1> IP2: <W4, P4>

S4 IP1: <W3, P3> IP2: <W2, P2>

Mutation

Metrics

- Path Latency
- Protection Tolerance
- Bandwidth Utilization

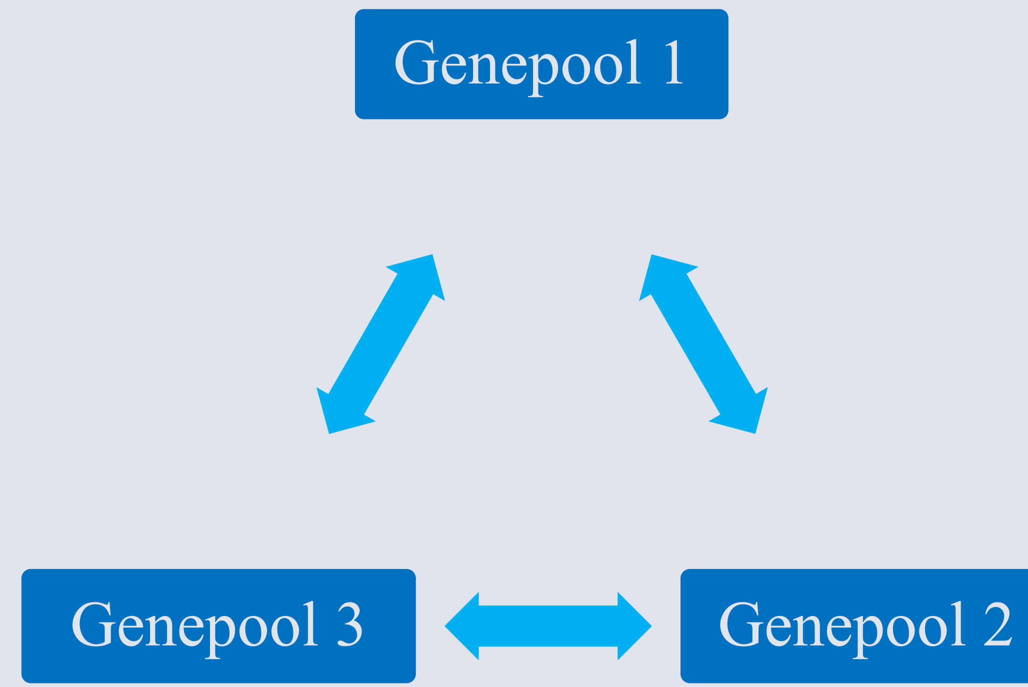
Fitness Evaluation

Building Blocks

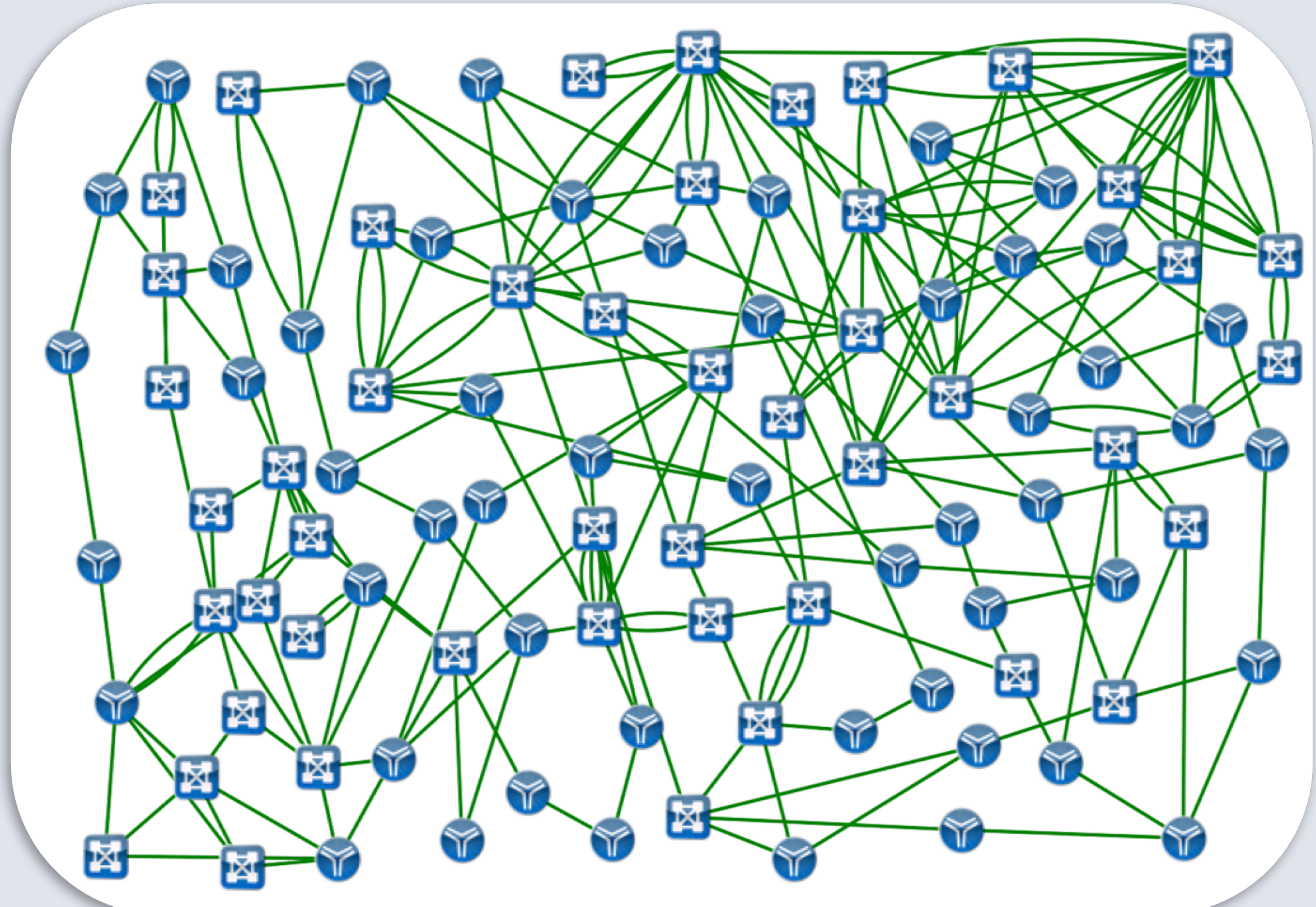
- Policy Framework
- Optical Engine
- Survivability Analysis Engine

Island Approach

- Multiple GA’s Run in Parallel
- Solutions moved between genepools at intervals
- Improves Genepool Diversity
- Mitigates Search Stagnation on Local Optima
- Reduces Time To Find Optima
- Provides Result Consensus



Facebook Backbone Network



FB Backbone Case Study - Modeling Assumptions

Topology

- FB network world wide network has 100+ sites and 200+ links
- Fiber distance used as IGP metric
- Fiber capacity is 9.6Tbps
- Optical reach is 2500 km
- Fiber operational cost is assumed

Equipment

- IP interface is 100G with utilization of 80%
- Shortest Path on L3 layer
- CD ROADM architecture
- Fixed Grid technology
- Optical interface at 100G
- Real Equipment costs modeled

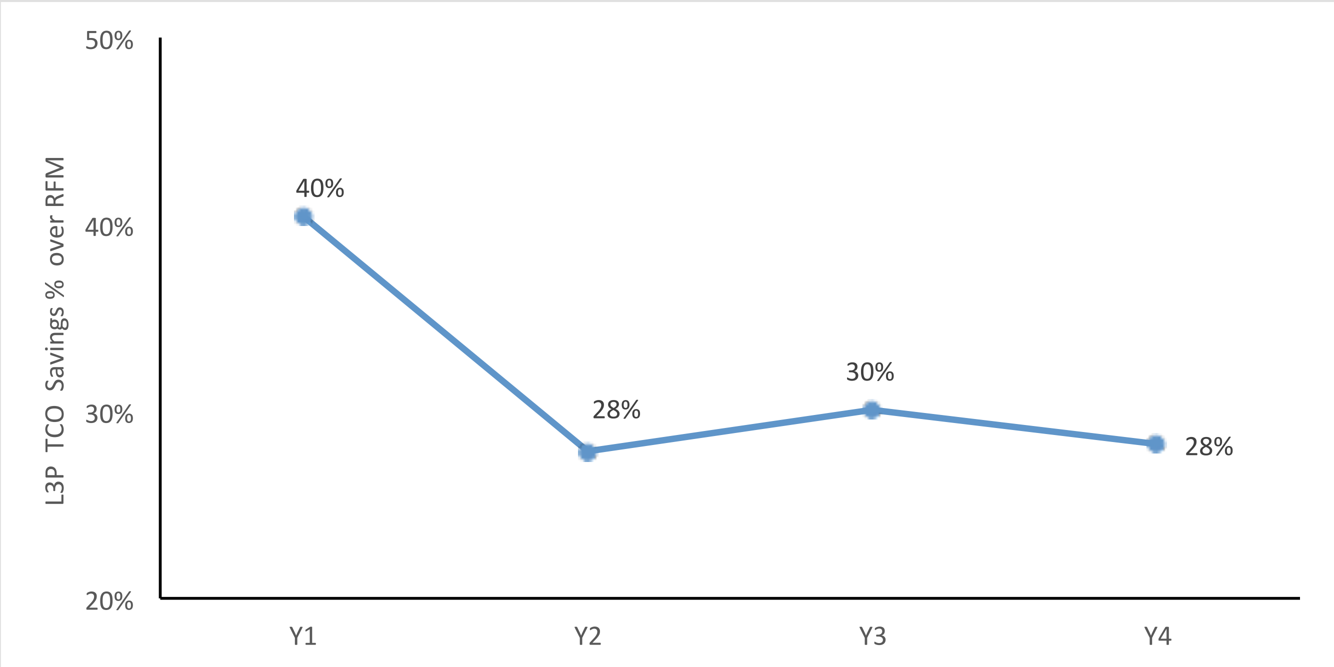
Traffic

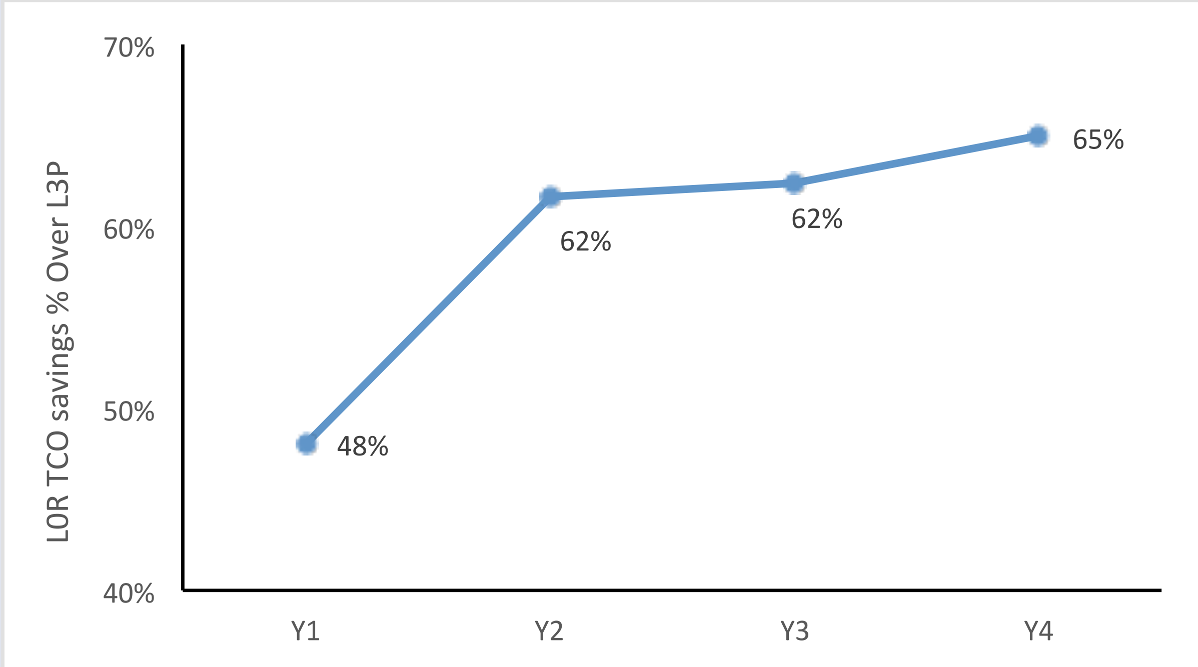
- Initial traffic volume in Y1 is 35T
- Additional years Y2, Y3, and Y4
- Assume 50% growth YoY
- 50% of services is assumed to be low priority

Objective

- Dimension for single fiber failures
- Optimize for Network Total Cost of Ownership

L3P Benchmarks





Normalized Network TCO

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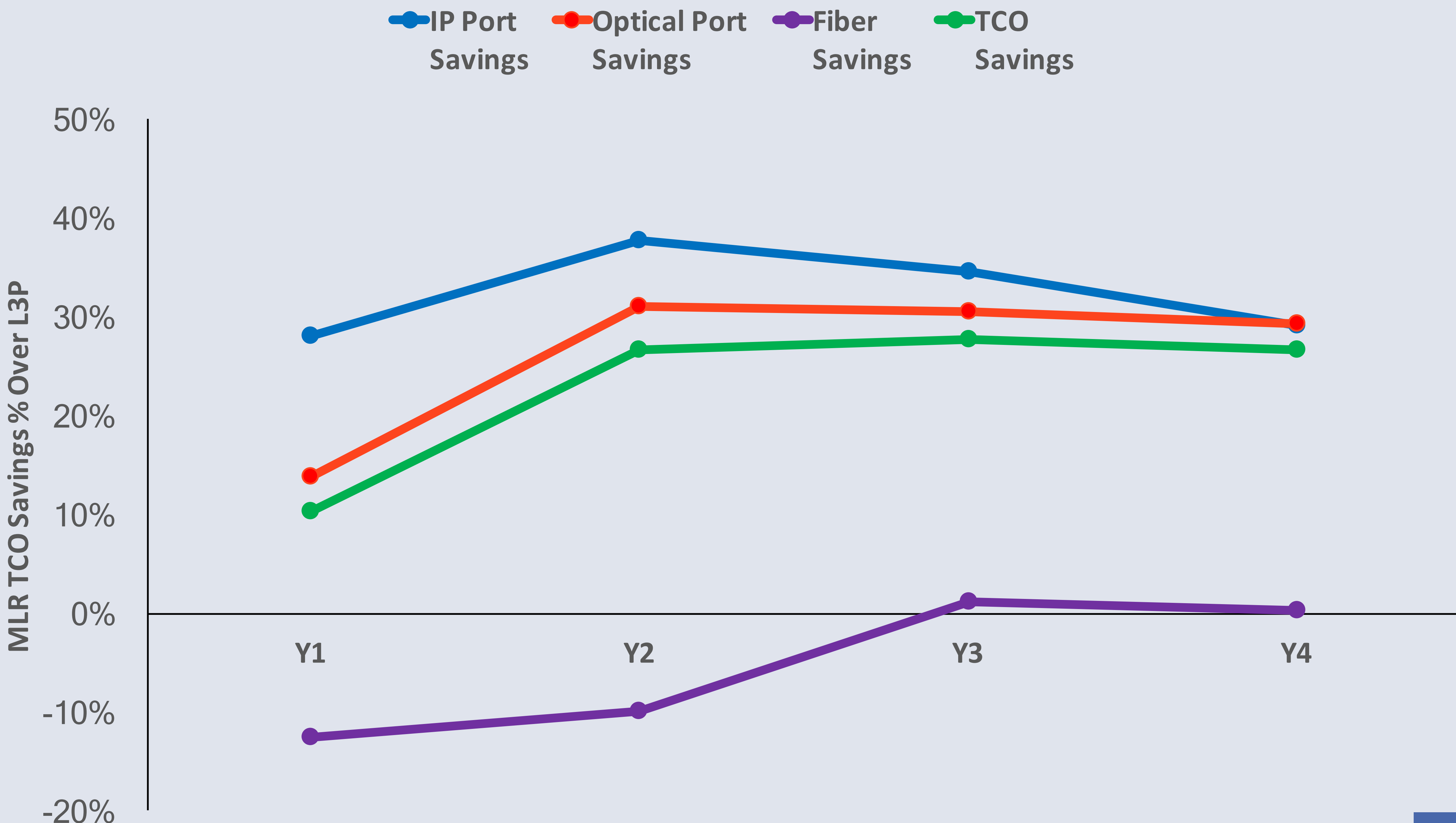
MLR Vs L3P TCO Savings (%)



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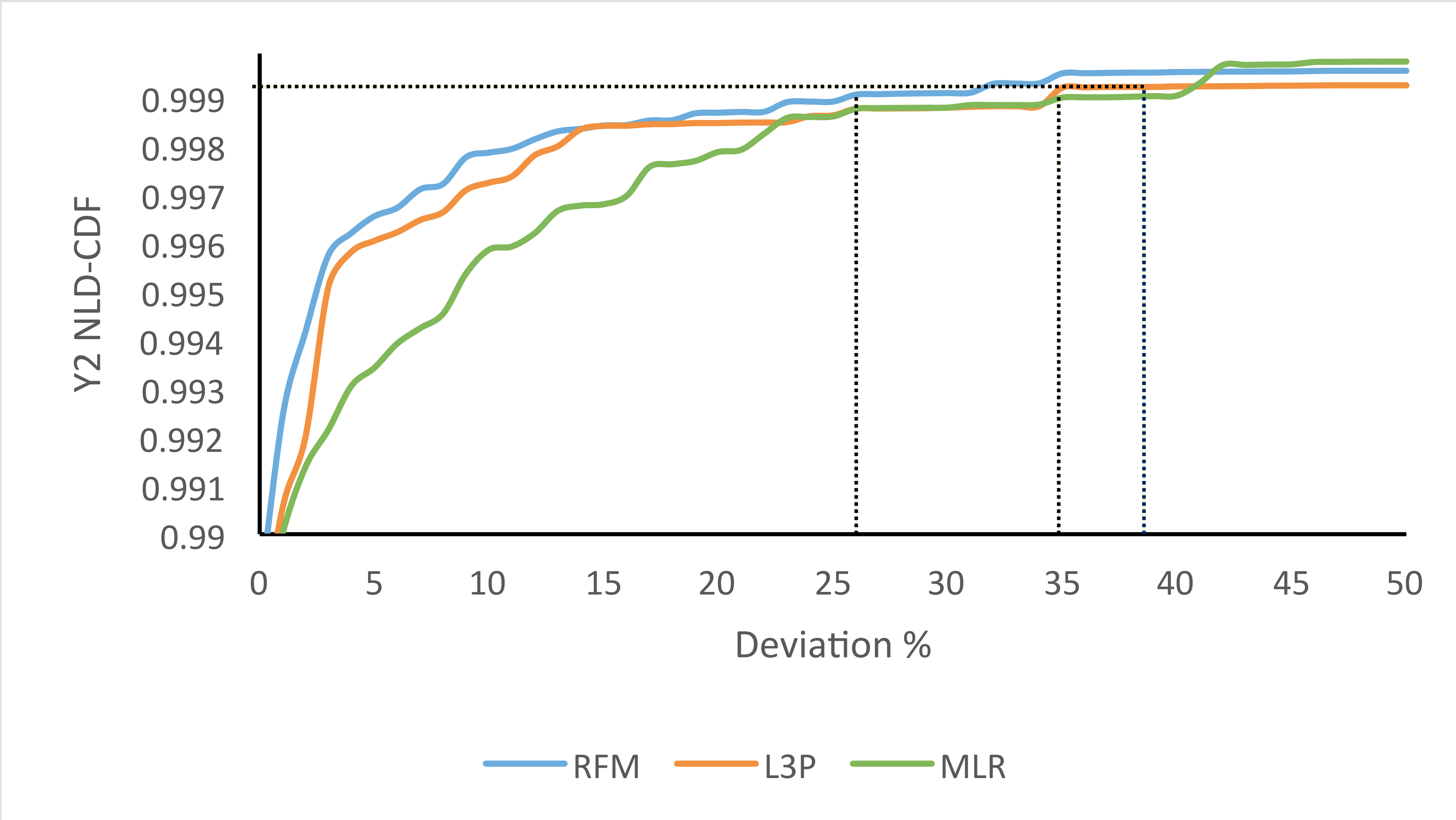
Y2 Worst Case Network Latency Deviation CDF



Conclusions

- Multilayer Design can achieve significant network savings when compared with single layer design
- By restoring low priority traffic in optical layer, and high priority traffic in IP layer, significant network savings is achievable without compromising on QoS
- Future extensions would include traffic engineering in a multilayer perspective
- Challenges to be addressed by optical vendors - Online engine for optical closures, Open APIs for real time path computation, Optical port cost reduction

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Thank You
Q & A
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Novelty of the study

- Network Optimization which optimizes TCO assuming real costs of IP ports, optical ports, and fibers
- Scales to network in excess of 100+ sites and 200+ optical links.
- Fully automatic design tool that solves both green field and brown field multilayer design and explores beyond shortest paths in L0
- Distributed resilience and study based on Facebook backbone with realistic traffic projection

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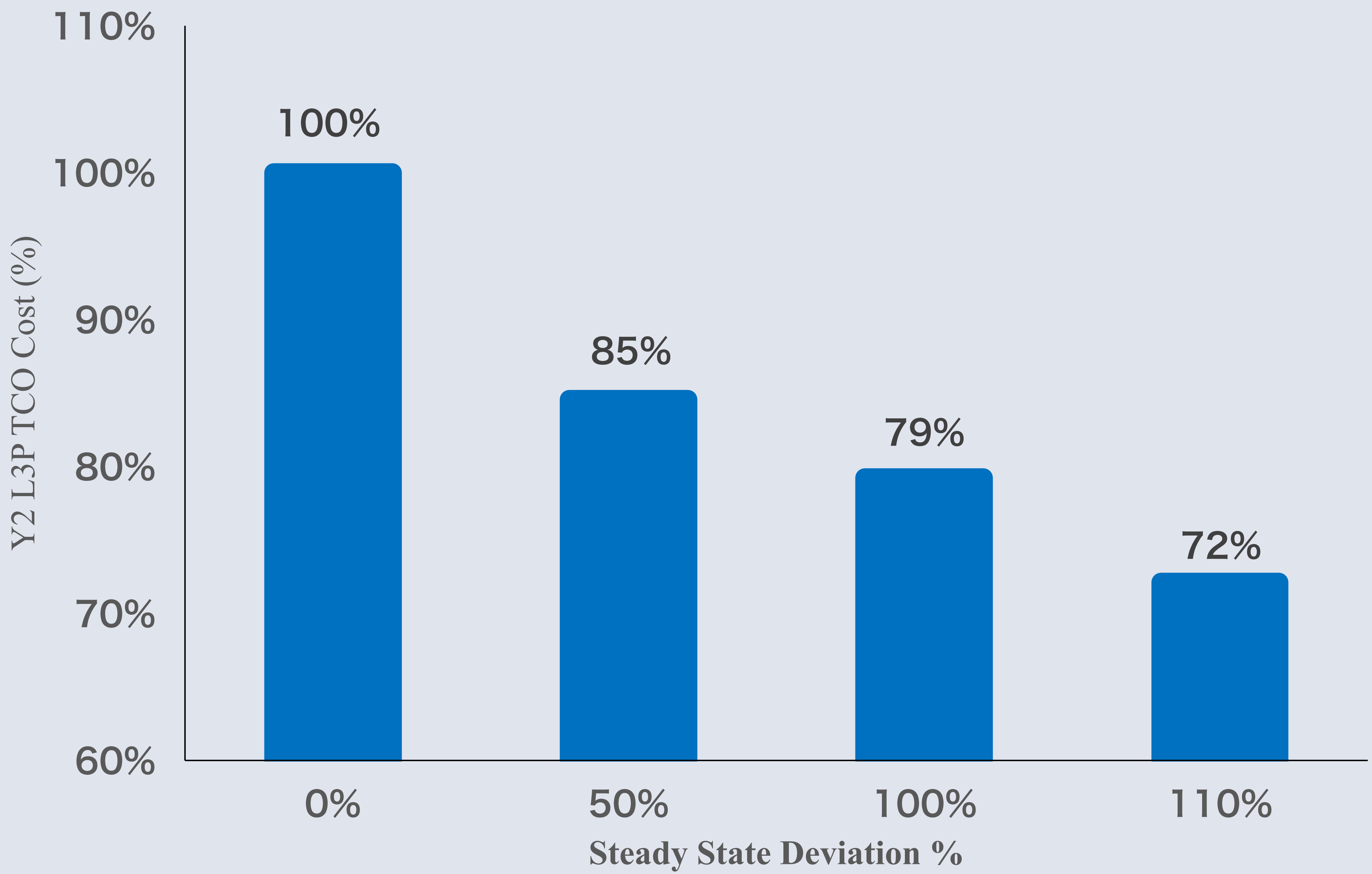
L3P TCO Normalized Cost(%)



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