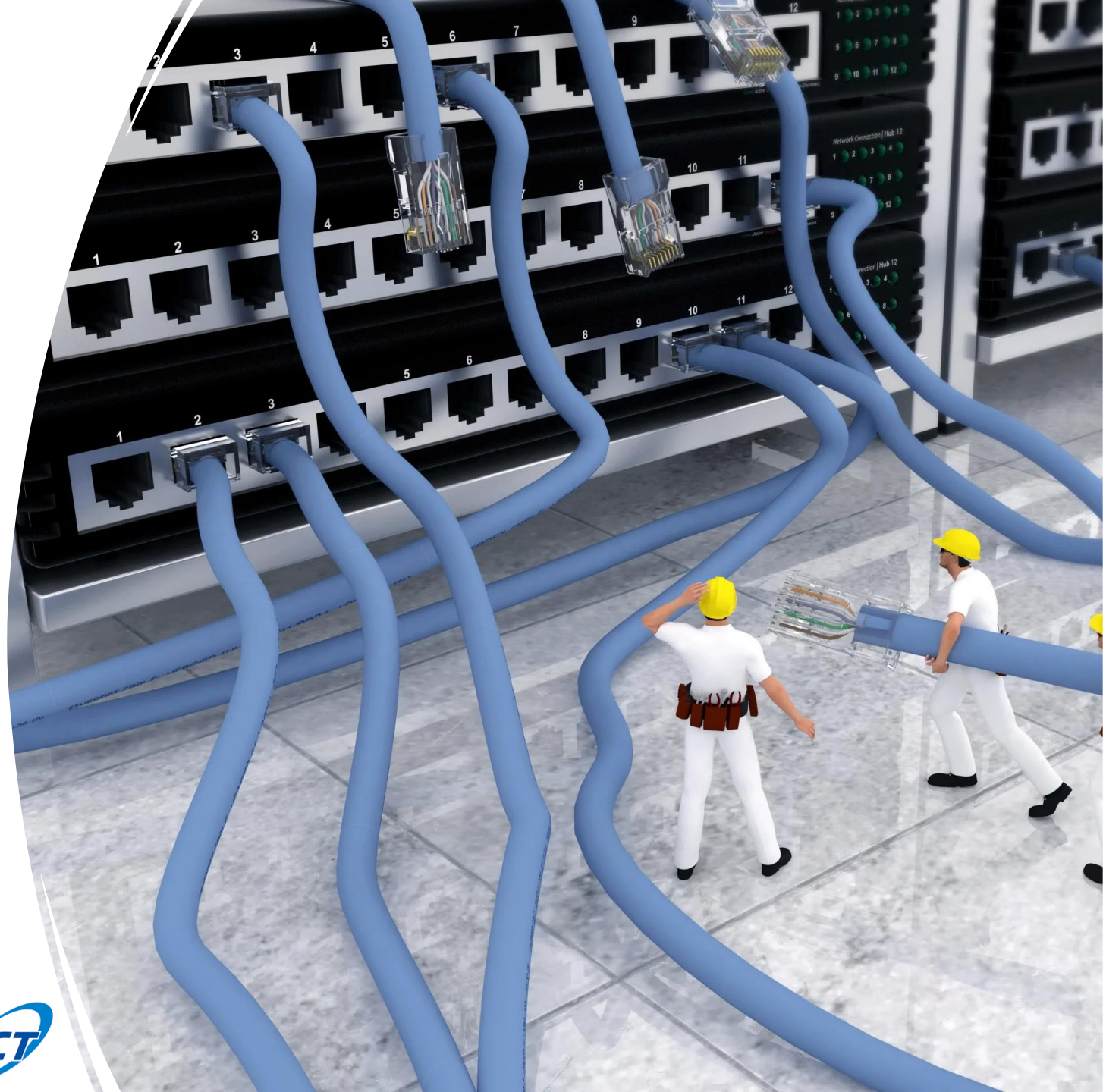
Task 4: Preemptive and Early Failure Detection and Management

July 28, 2023

Presented by:

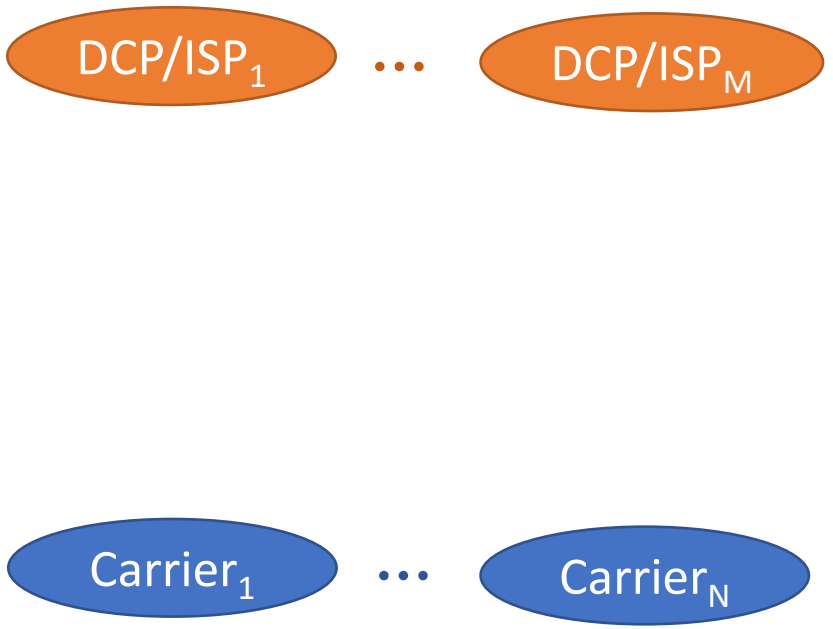
Forough Shirin Abkenar



General System Architecture

The interconnection between different entities in the ecosystem

General System Architecture



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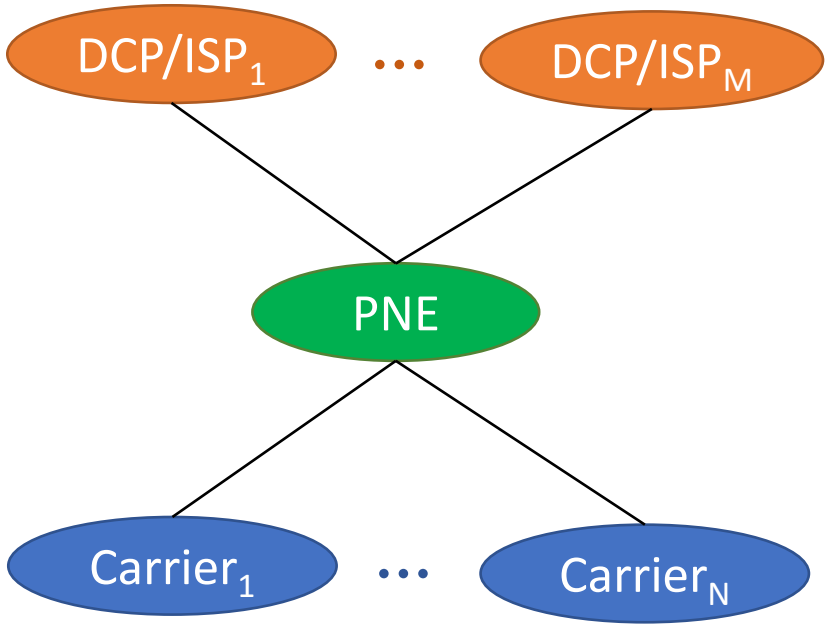
General System Architecture



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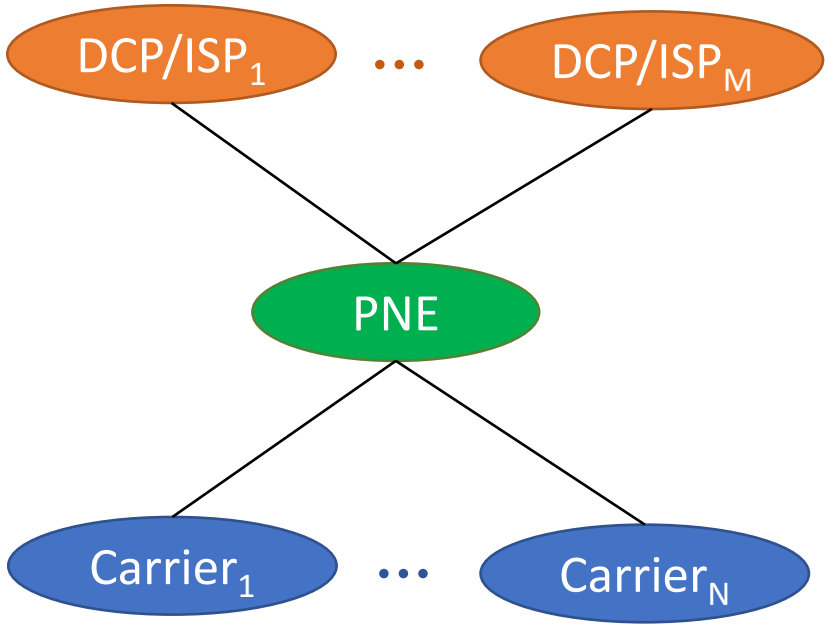
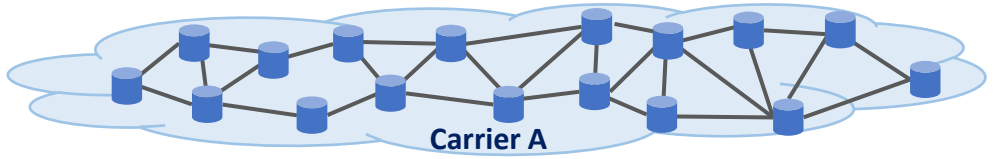
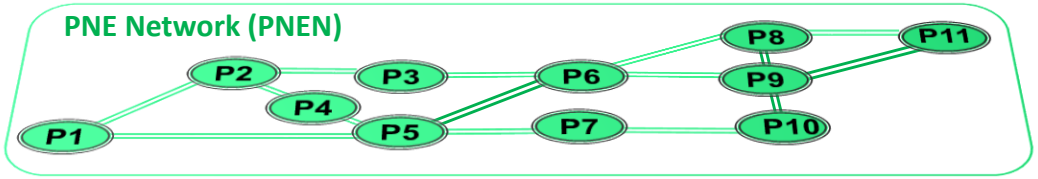
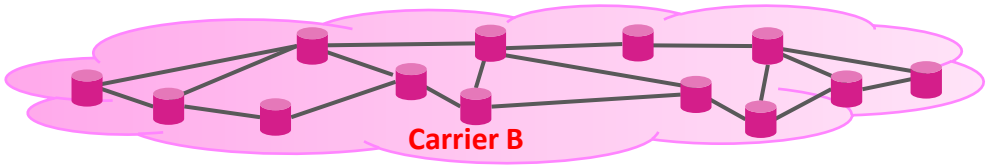
General System Architecture









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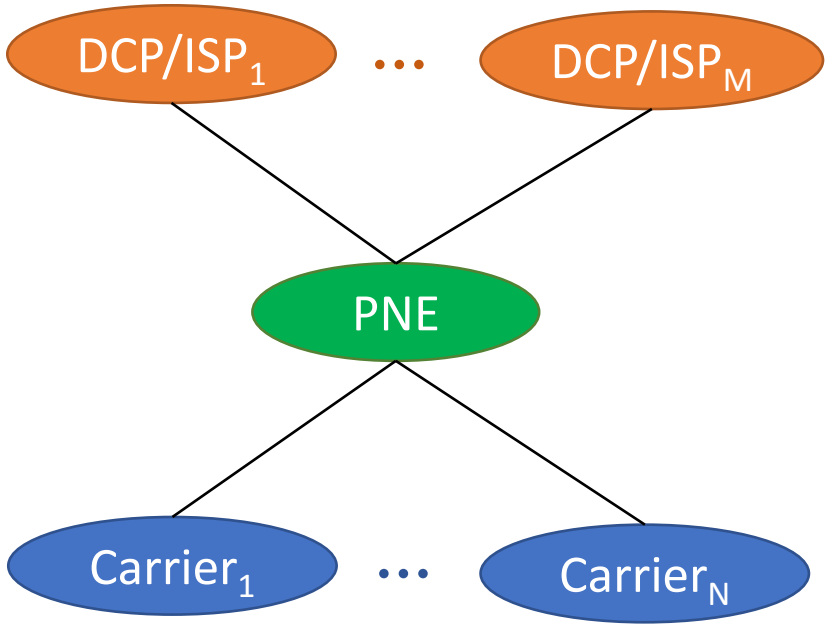
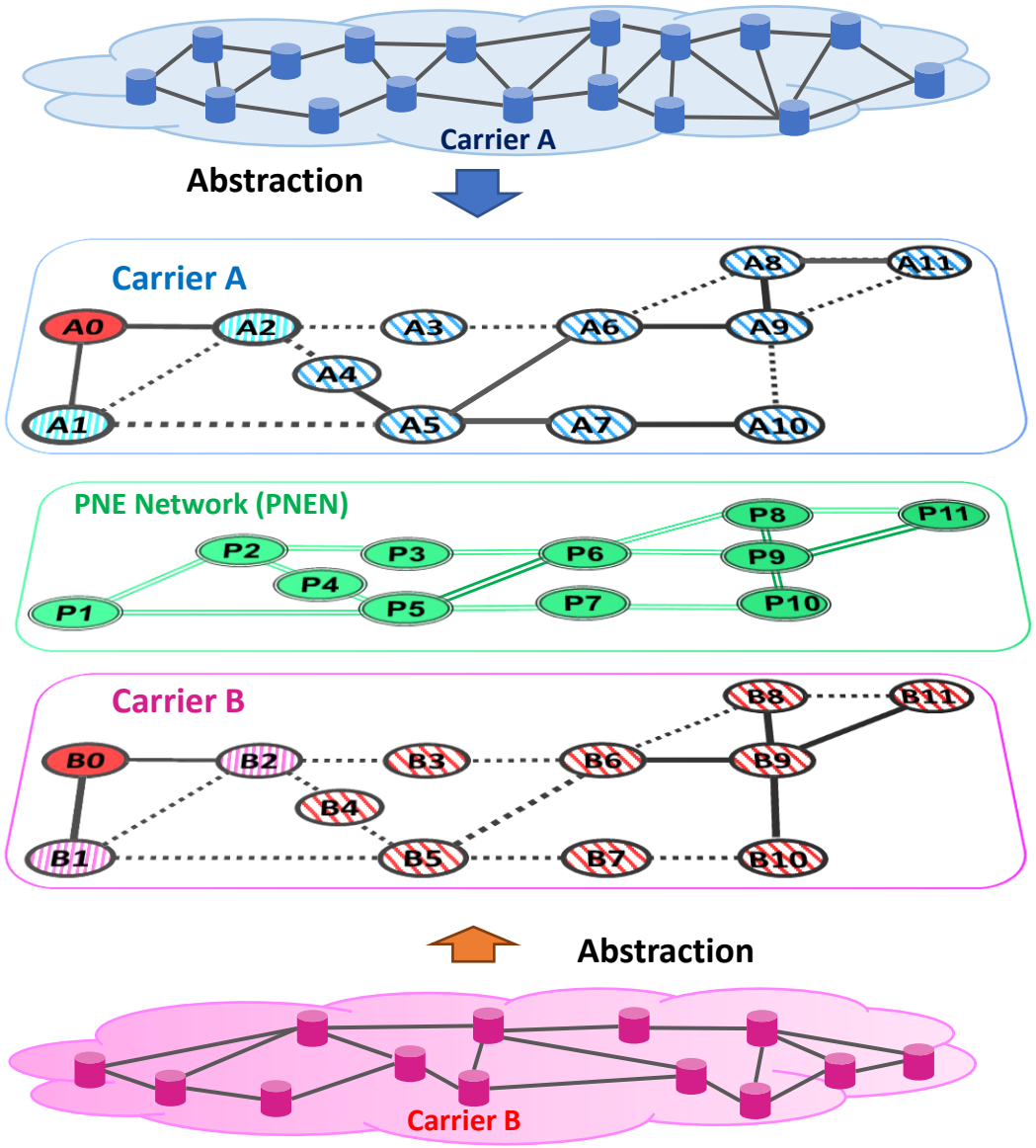
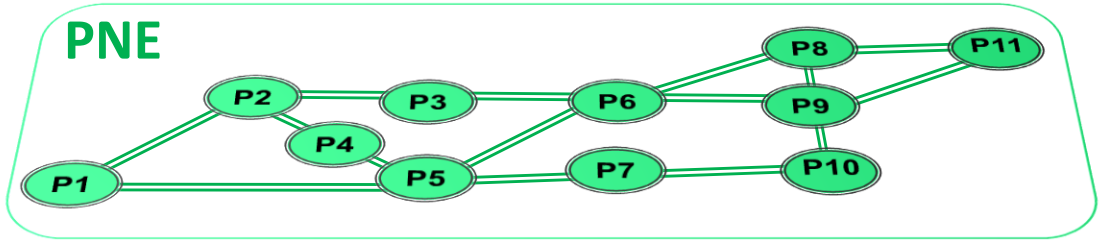
General System Architecture

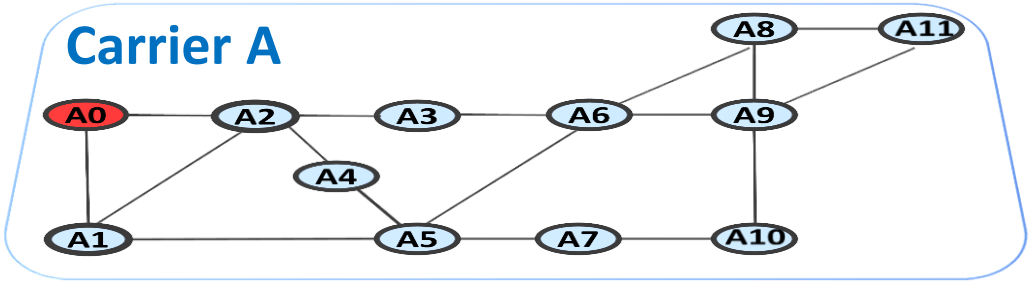


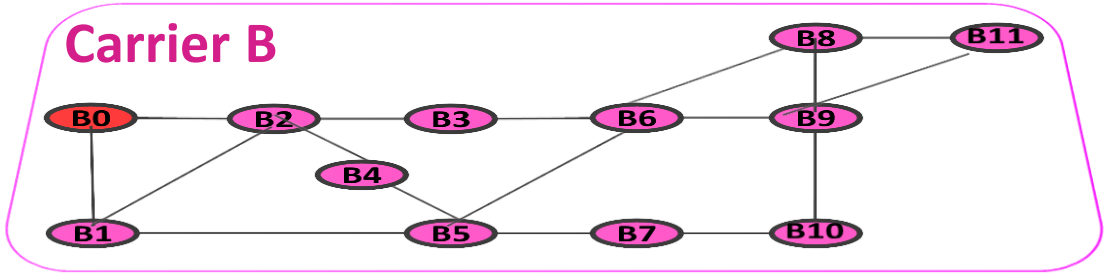


The interconnection between different entities in the ecosystem

Preemptive and Early Failure Detection and Management







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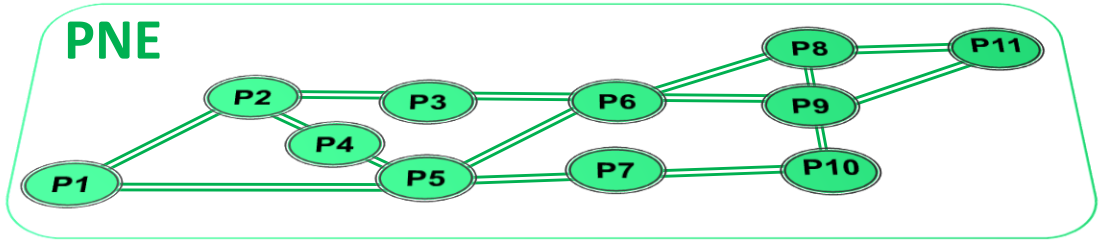
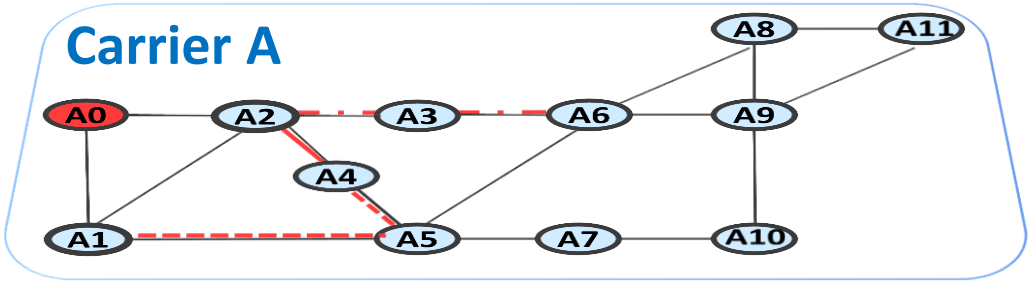
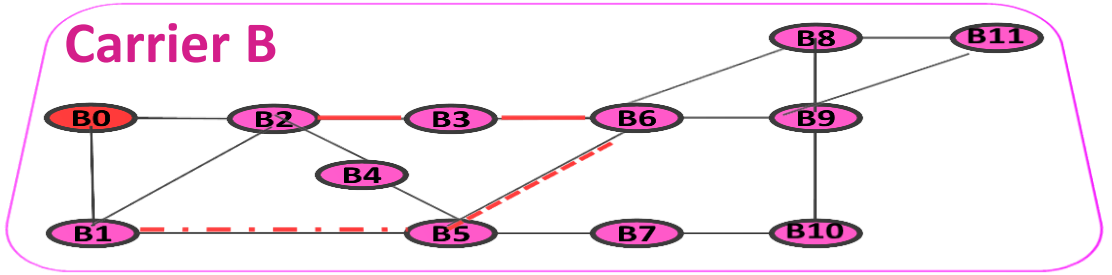
Preemptive and Early Failure Detection and Management







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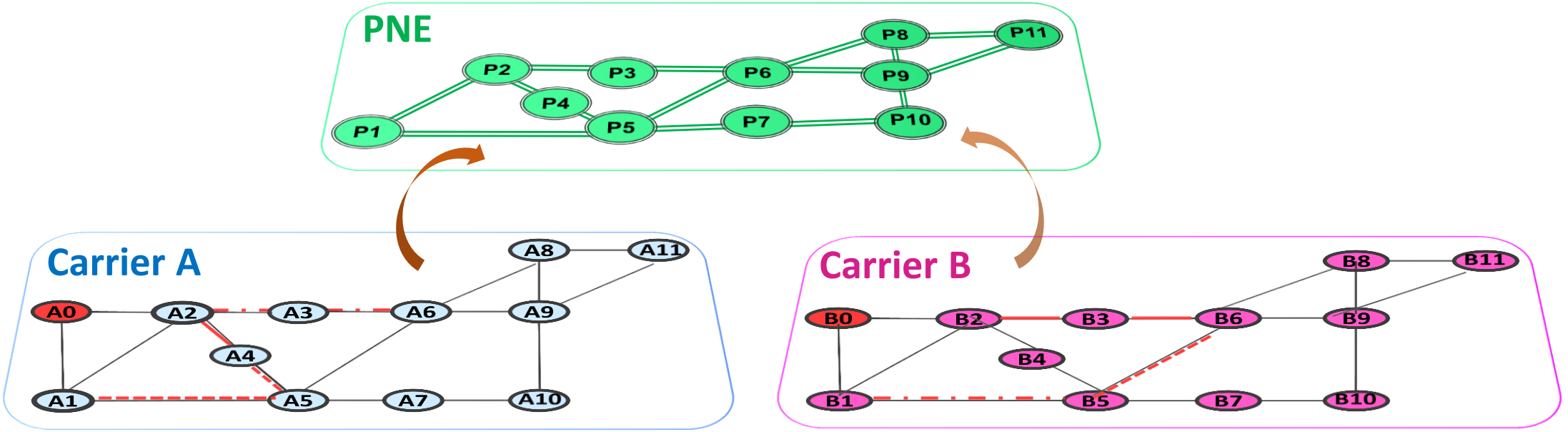
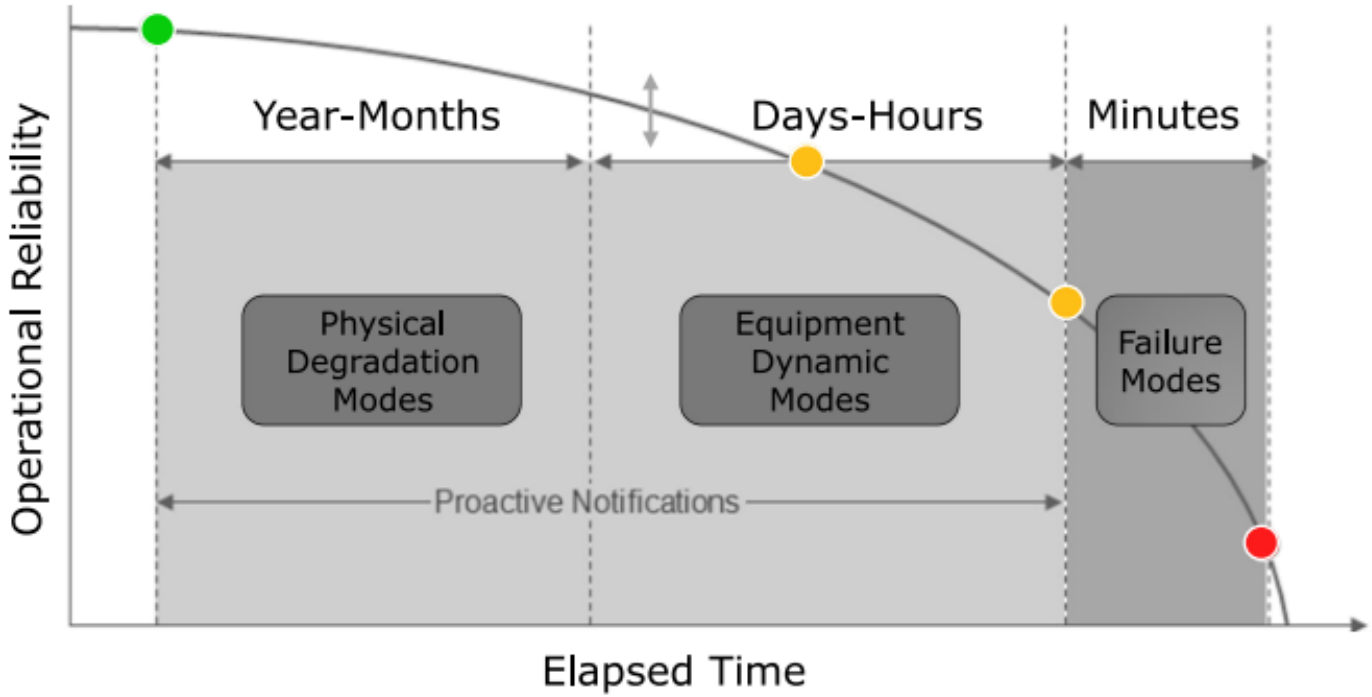
Preemptive and Early Failure Detection and Management



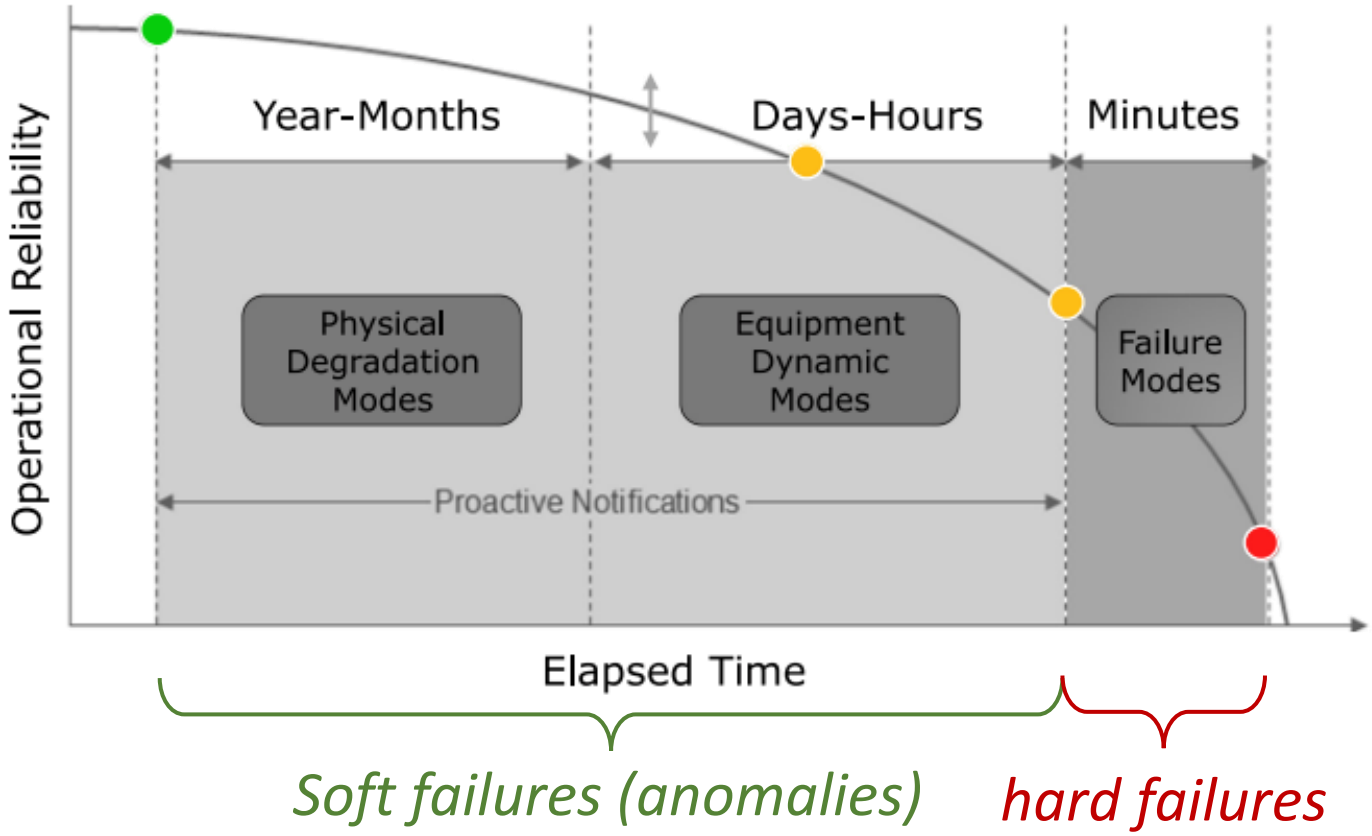
Degradation/disconnection at the physical layer needs ***preemptive*** *and* ***early*** *detection and management*

Preemptive and Early Failure Detection and Management



D. Rafique, T. Szyrkowiec, H. Grießer, A. Autenrieth and J. -P. Elbers, "Cognitive Assurance Architecture for Optical Network Fault Management," in *Journal of Lightwave Technology*, vol. 36, no. 7, pp. 1443-1450, 1 April1, 2018.

Preemptive and Early Failure Detection and Management



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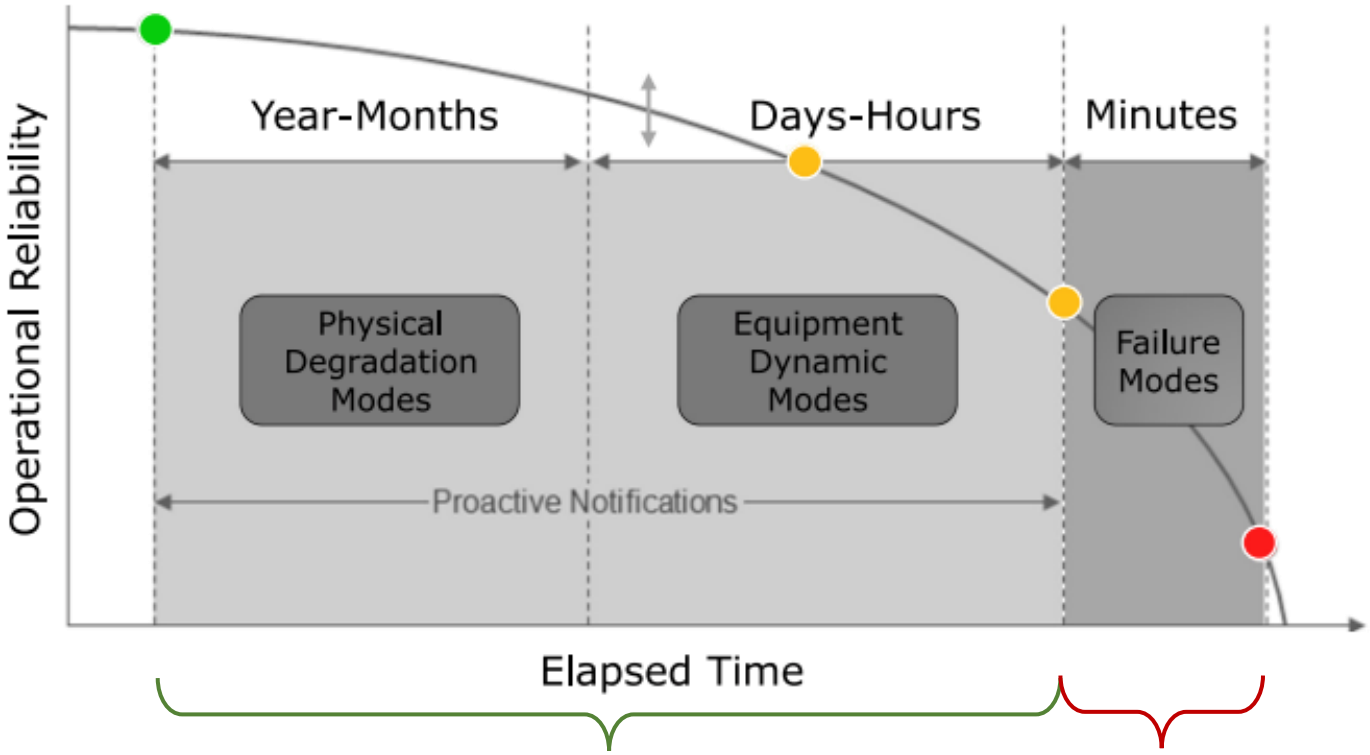
Preemptive and Early Failure Detection and Management

PREEMPTIVE



Gradual degradation of the network operations

Soft failures (anomalies)

hard failures

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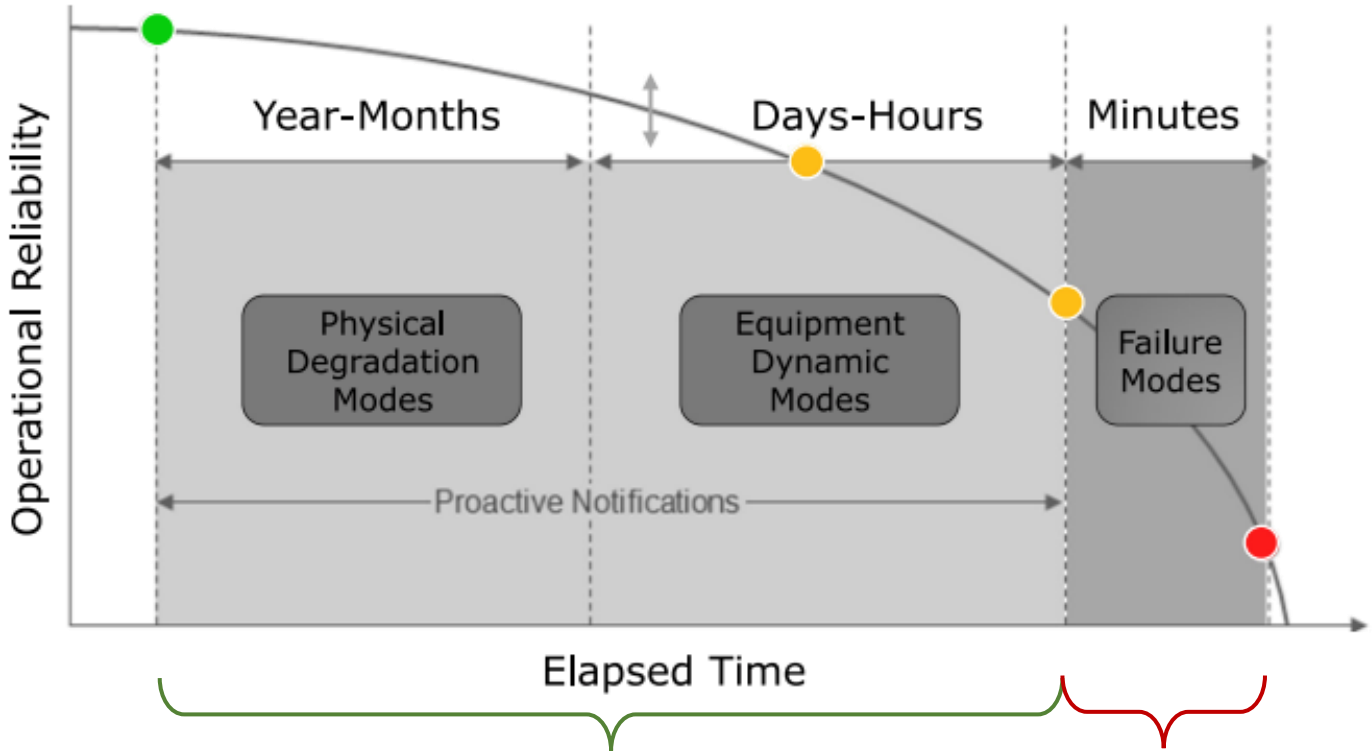
Preemptive and Early Failure Detection and Management

PREEMPTIVE

EARLY



Gradual degradation of the network operations

Immediate service disruptions

Soft failures (anomalies)

hard failures

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Behavioral Modeling and ML Techniques for Threat Detection

Cisco Security Analytics (2020), “A deep-dive into the unique behavioral modeling and machine learning techniques for advanced threat detection and response [White Paper],” https://www.cisco.com/c/en/us/products/collateral/security/stealthwatch/white-paper-c11-740605.pdf.

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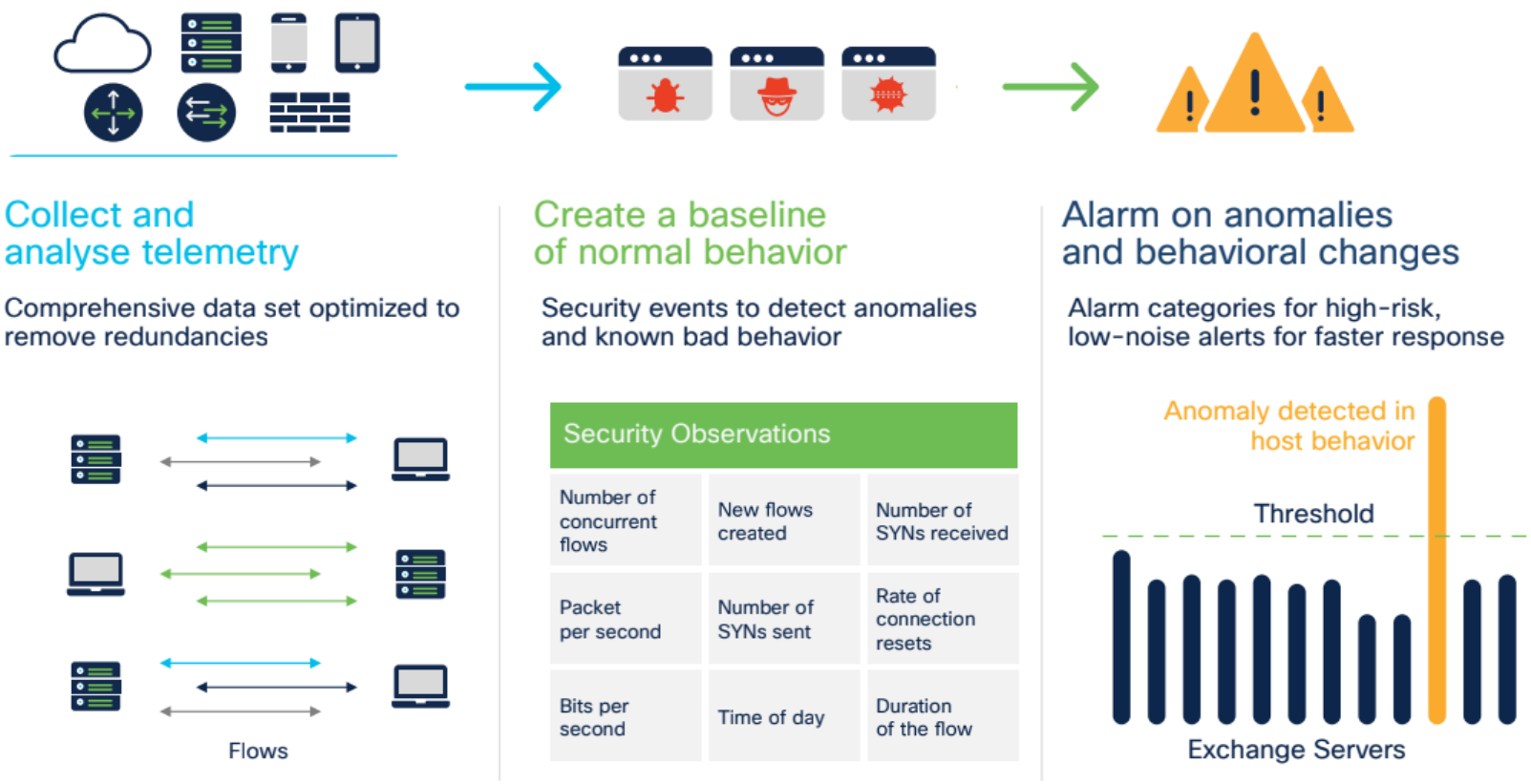

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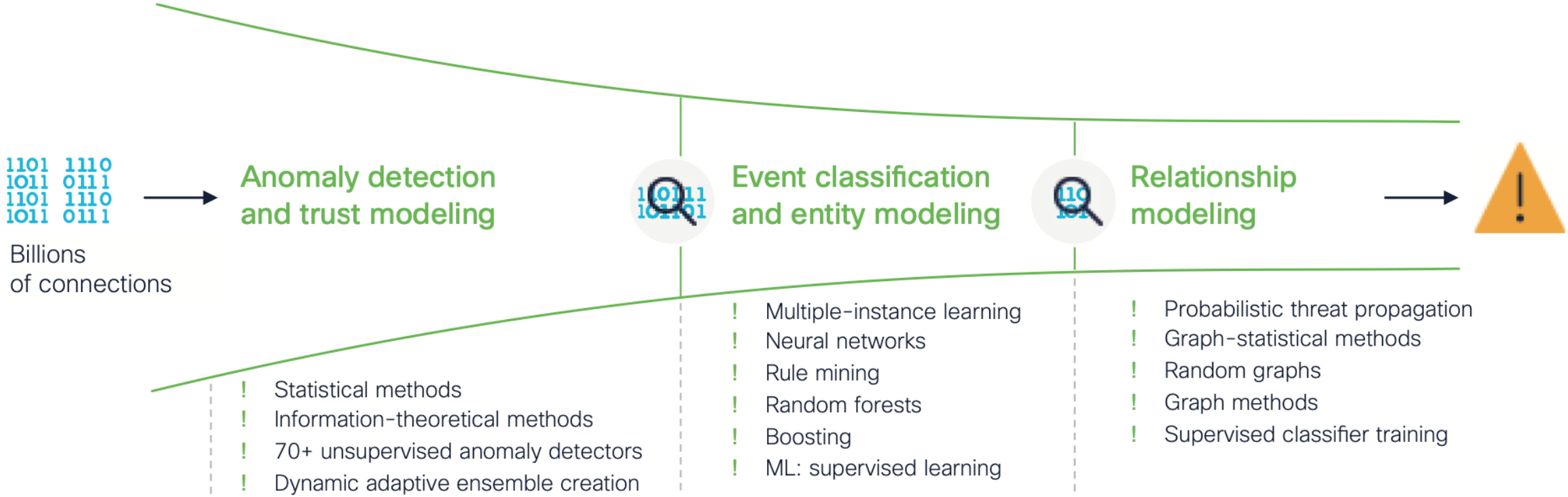

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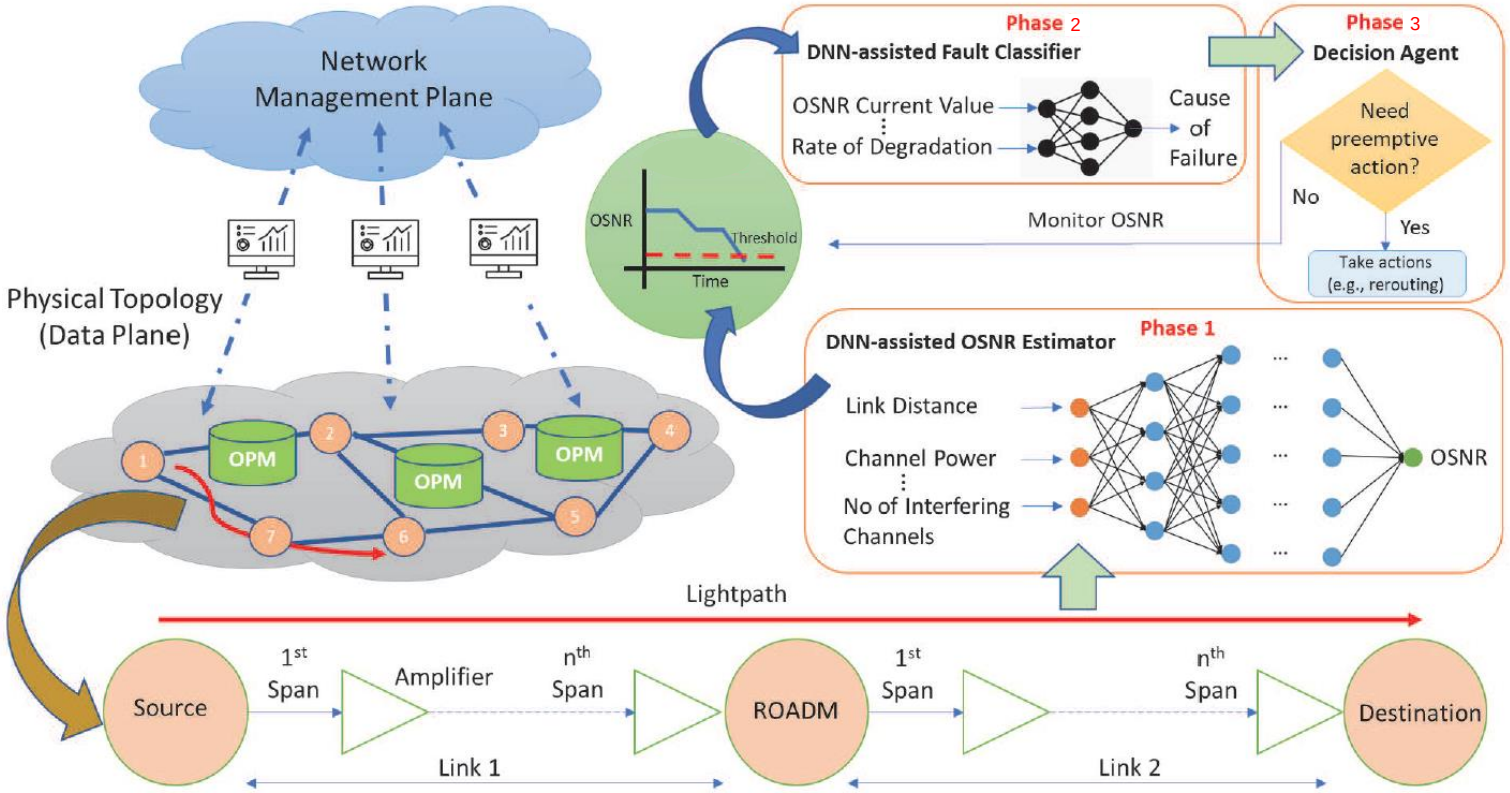
General Overview of The Proposed Framework in Single Entity

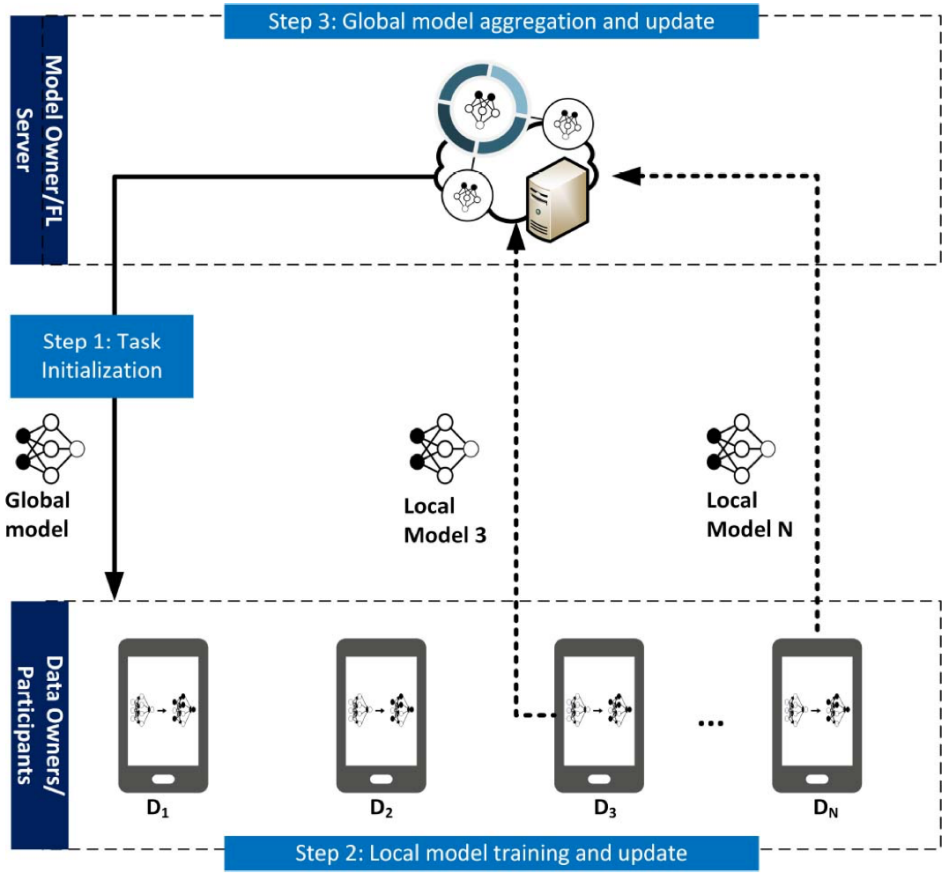


Preemptive failure detection and management (PFDM) framework

Highly Efficient Estimations and Classifications using Federated Learning

W. Y. B. Lim et al., "Federated Learning in Mobile Edge Networks: A Comprehensive Survey," in *IEEE Communications Surveys & Tutorials*, vol. 22, no. 3, pp. 2031-2063, thirdquarter 2020.

Highly Efficient Estimations and Classifications using Federated Learning



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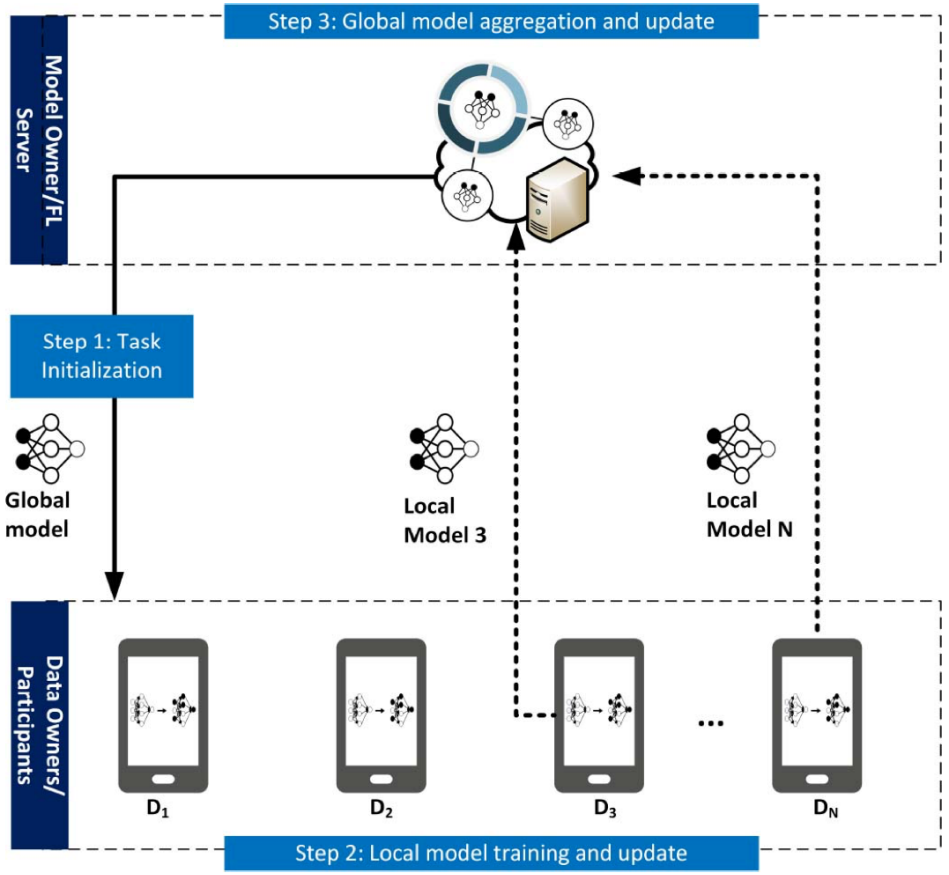
Highly Efficient Estimations and Classifications using Federated Learning

PNE

Carriers



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From Local to Federated

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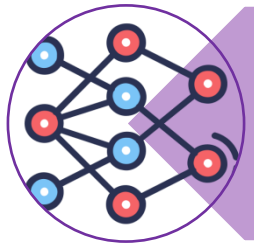
From Local to Federated

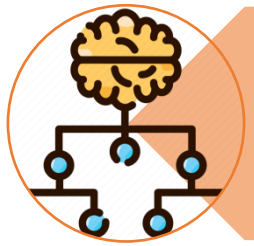
Federated Survivability Framework in Multi-Domain Optical Networks

Phases of The Proposed Framework



Phase I

- Abstraction and OSNR Estimation



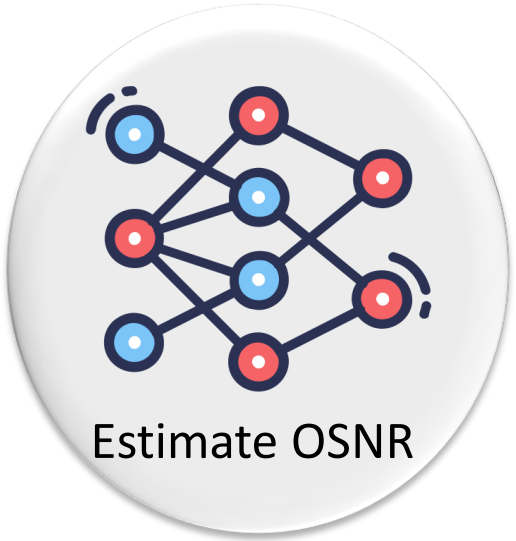
Phase II

- Failure Classification and Cost Evaluation

Phase III

- Negotiation and Post-Failure Action

Flow of The Proposed Framework



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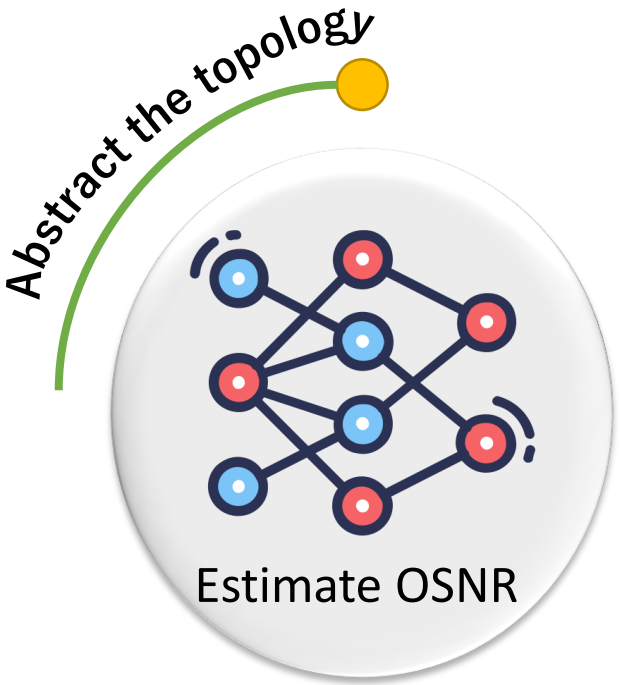
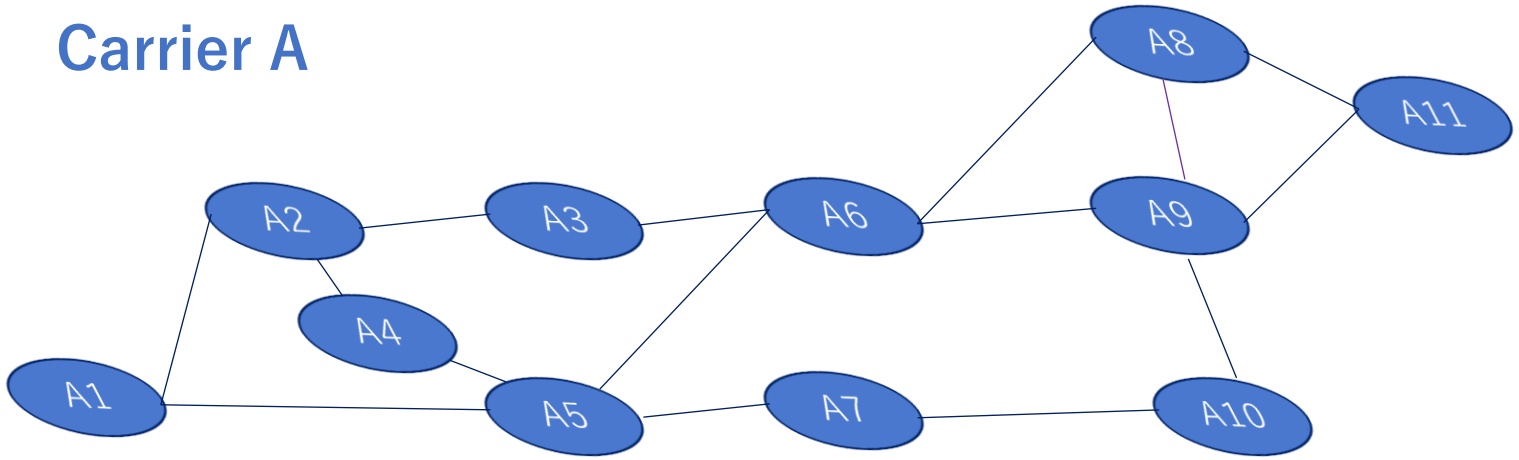


Phase I: Abstraction and OSNR Estimation



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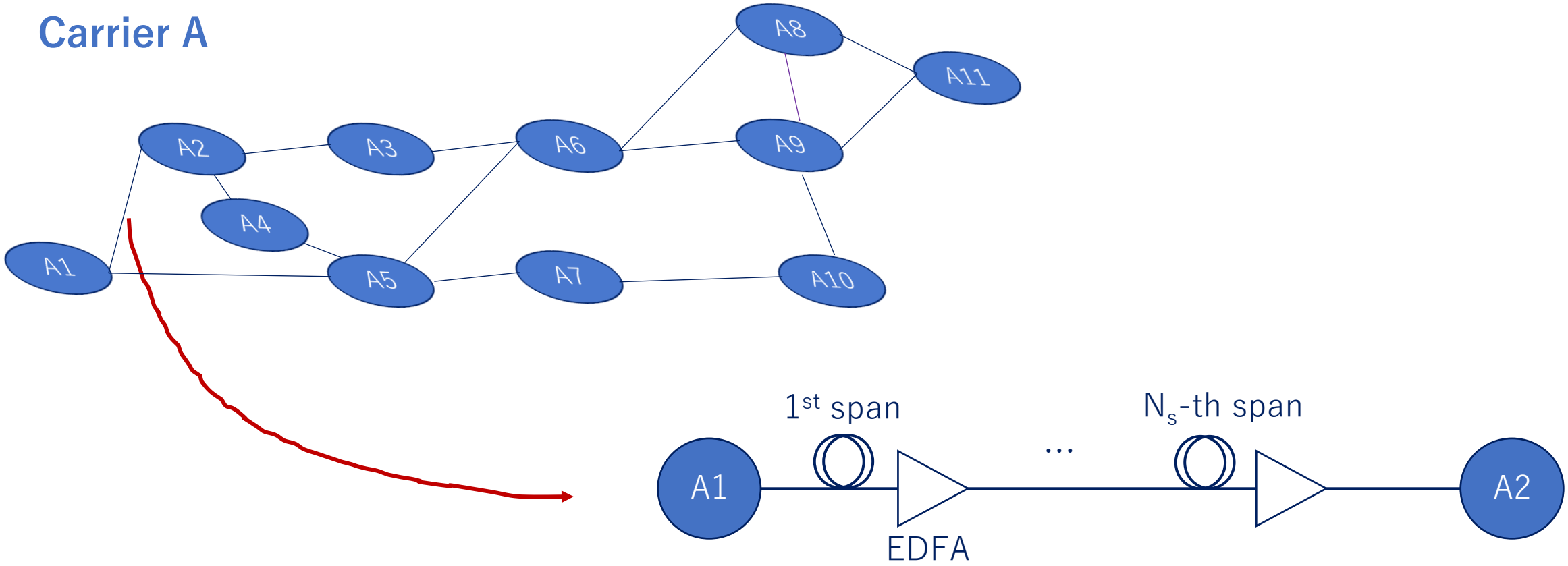
Phase I: Abstraction and OSNR Estimation



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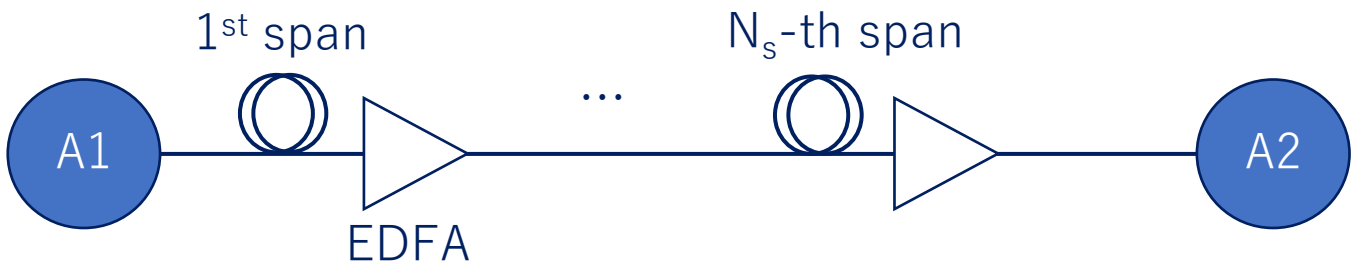

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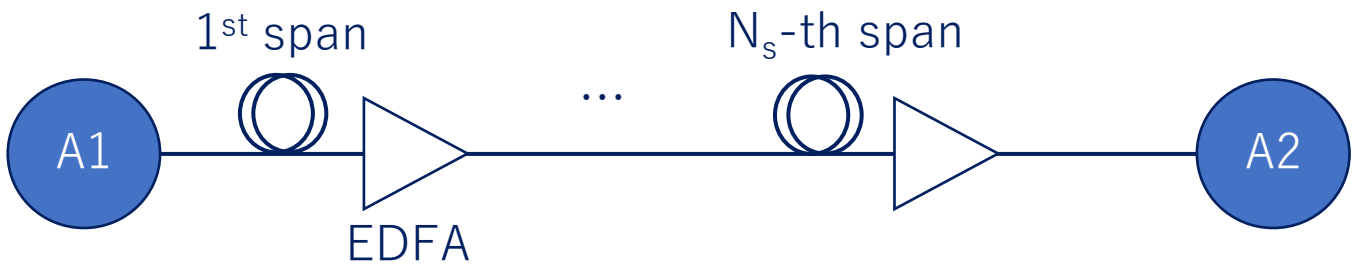
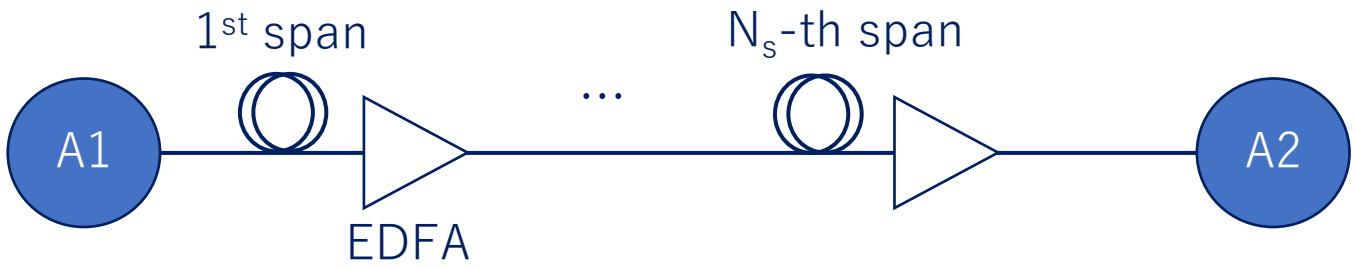


$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

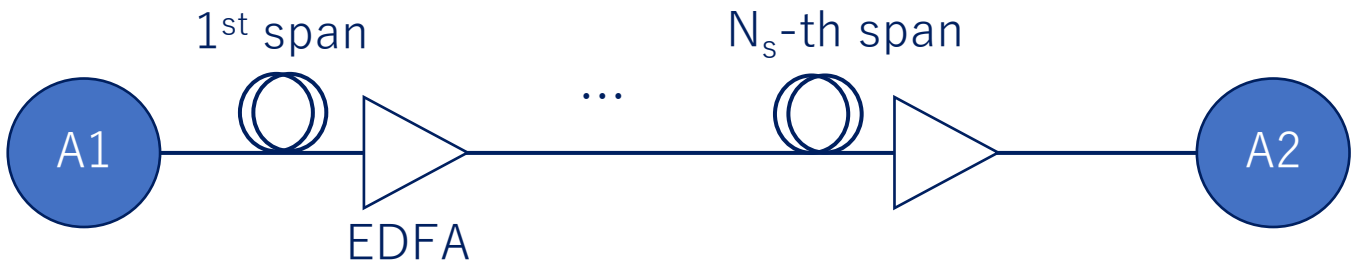
Phase I: Abstraction and OSNR Estimation



$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

frequency

Phase I: Abstraction and OSNR Estimation

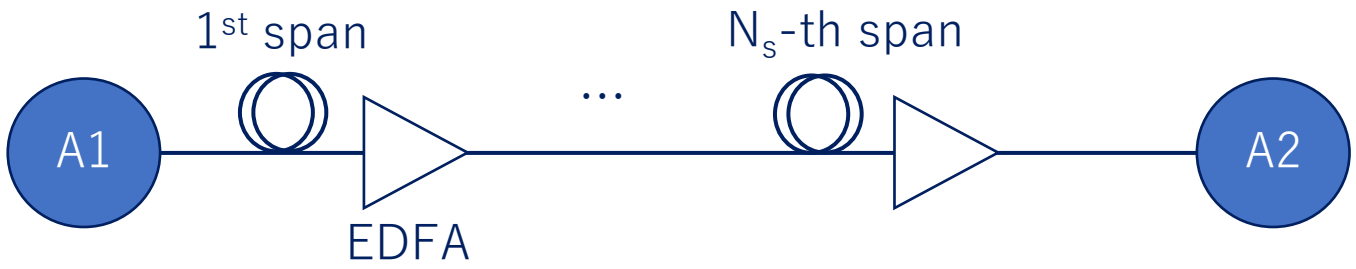


ASE noise

$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

frequency

Phase I: Abstraction and OSNR Estimation



ASE noise Cumulative NLI

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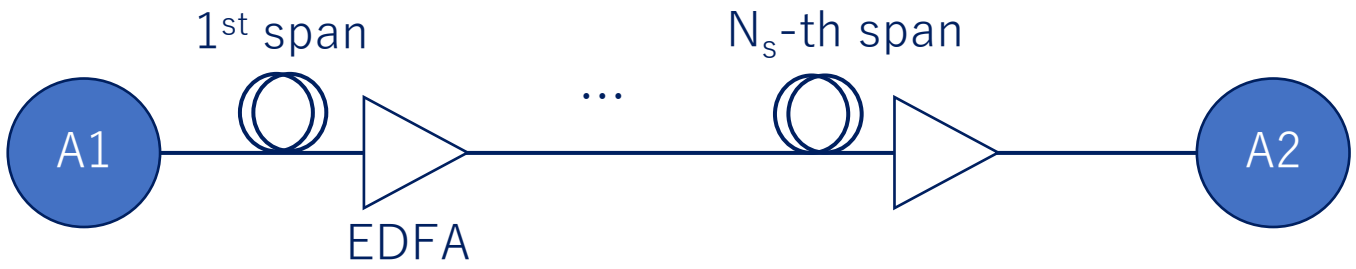
frequency

Phase I: Abstraction and OSNR Estimation



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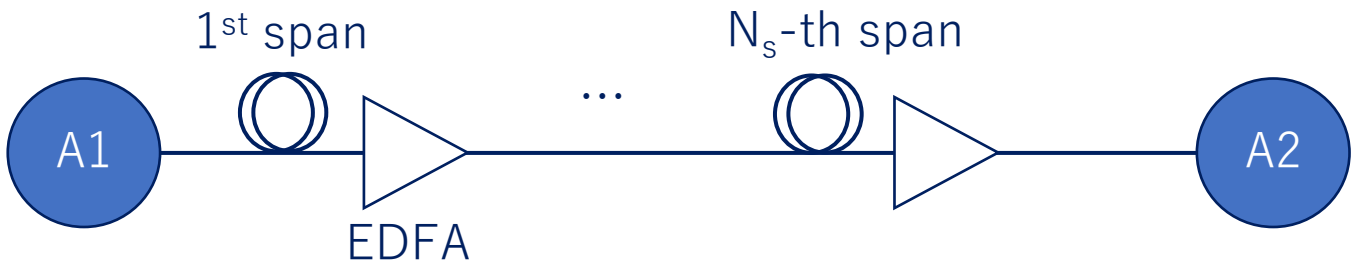
frequency

Channel power

Phase I: Abstraction and OSNR Estimation



$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

ASE noise

Cumulative NLI

frequency

Channel power

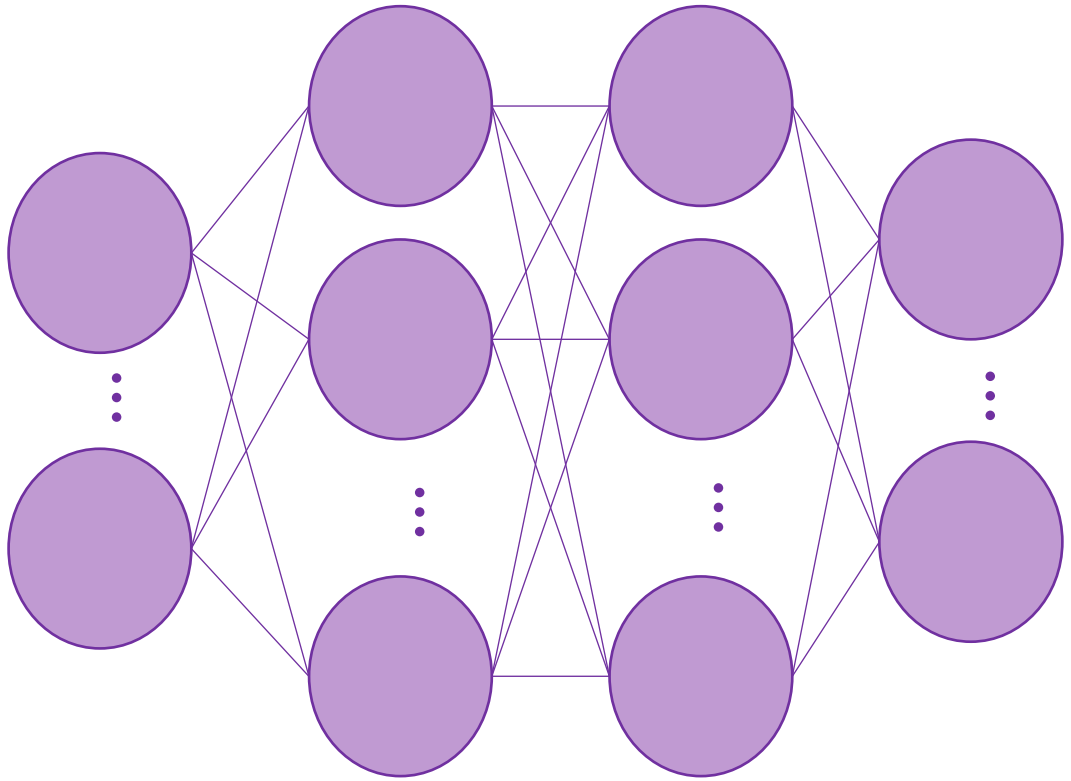
General Features
Channel Power
Modulation Level
Link Length
Frequency

ASE Features
# of span
Span length
Spontaneous emission factor
In-line EDFA gain
Reference Bandwidth
Planck constant

NLI Features
# of active channels
Power of interfering channels
NL coefficient
Phase mismatch
Loss

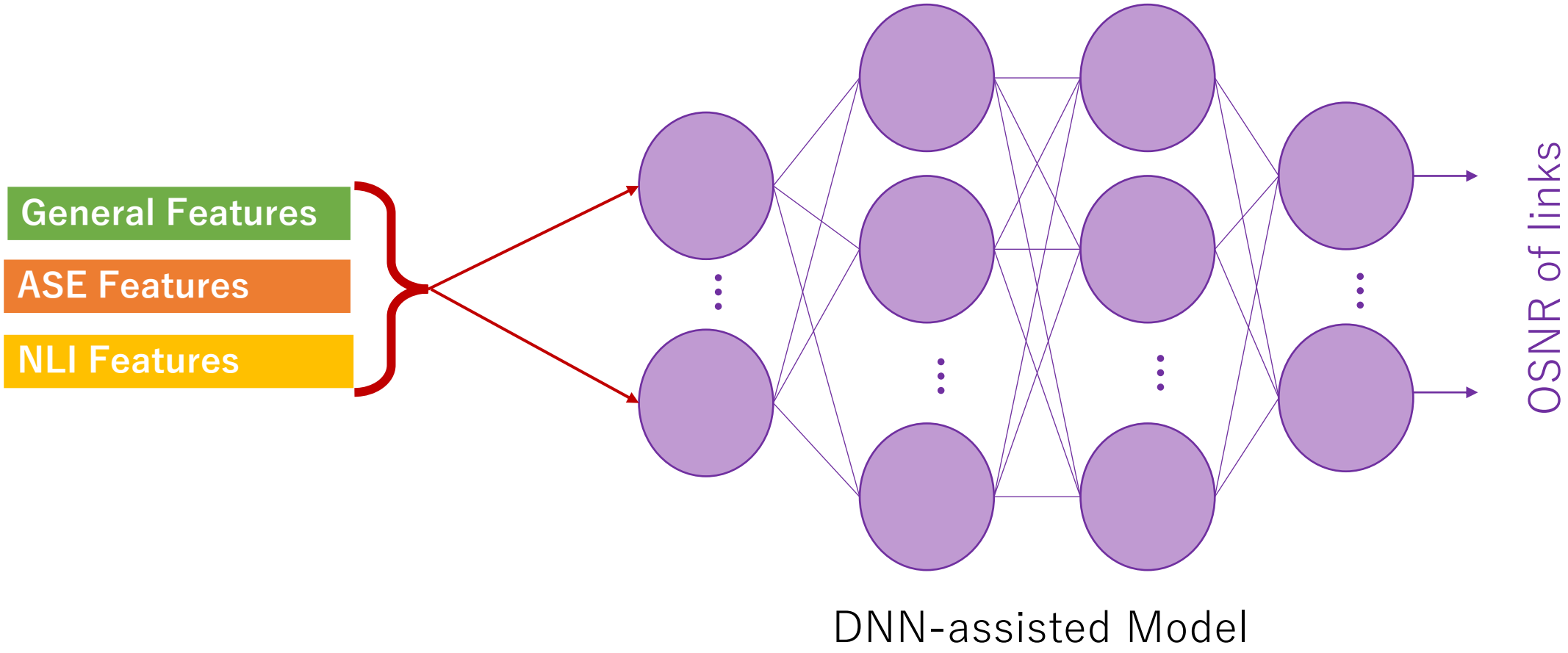
Phase I: Abstraction and OSNR Estimation

Phase I: Abstraction and OSNR Estimation



DNN-assisted Model

Phase I: Abstraction and OSNR Estimation



Phase I: Abstraction and OSNR Estimation

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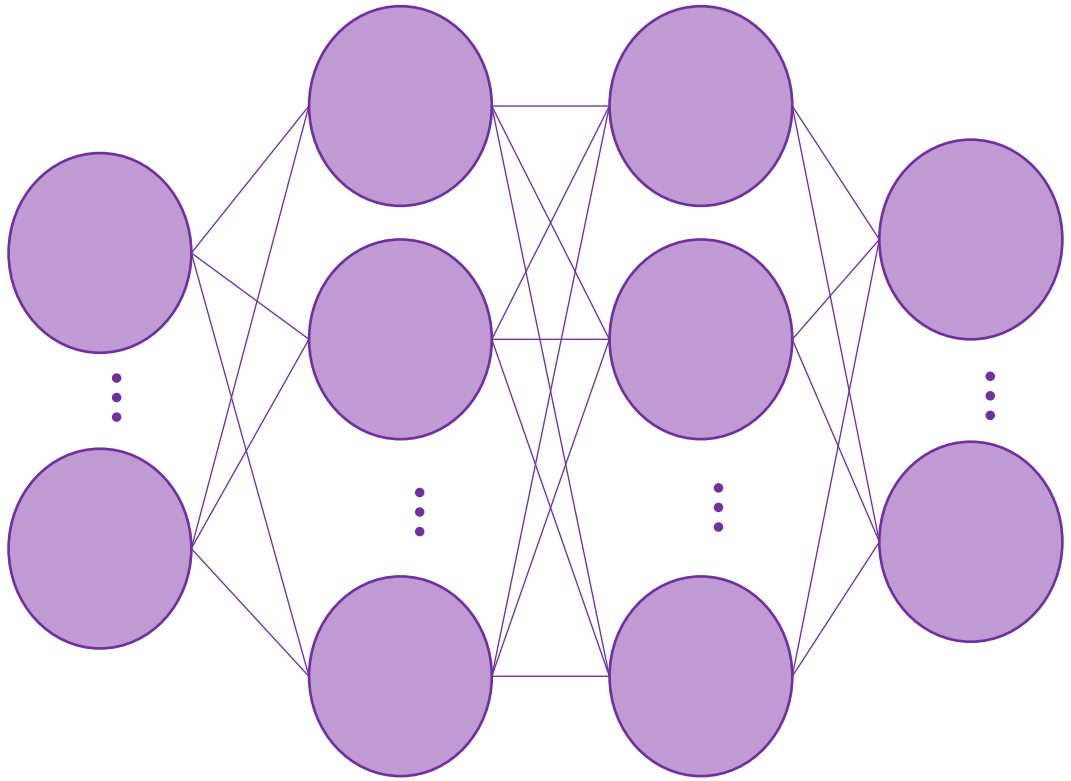
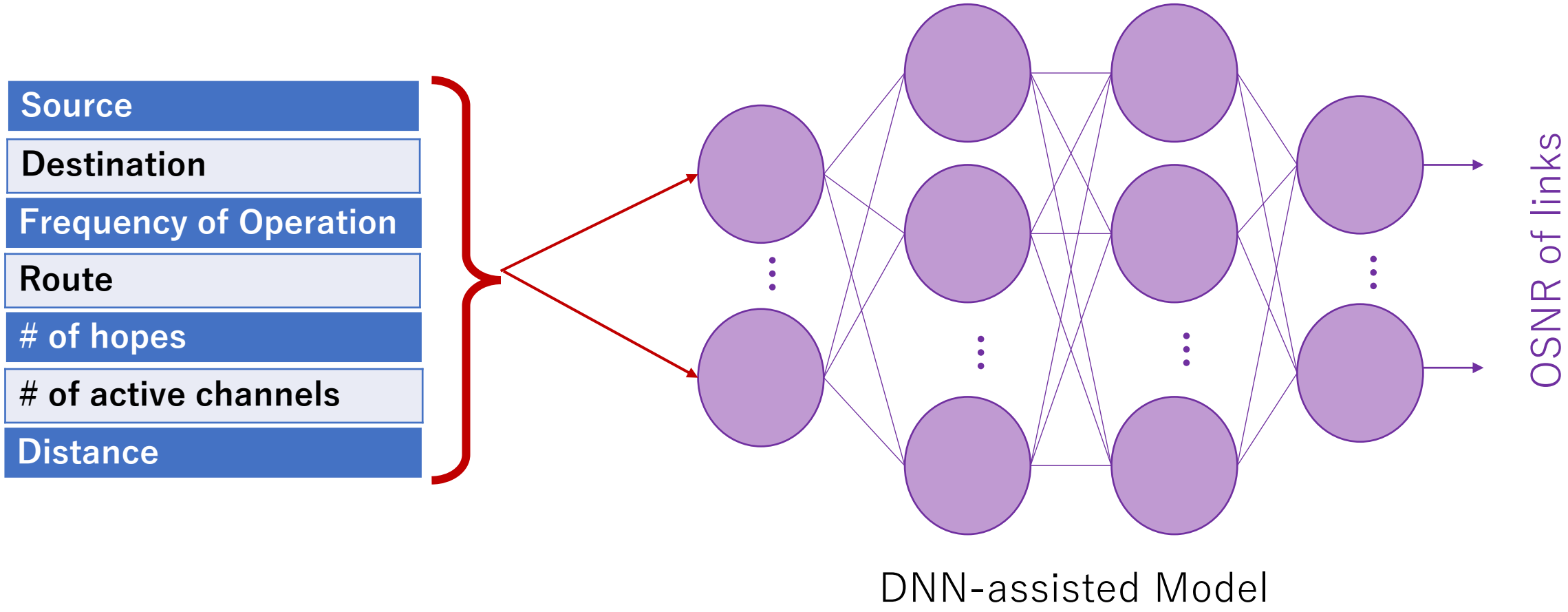
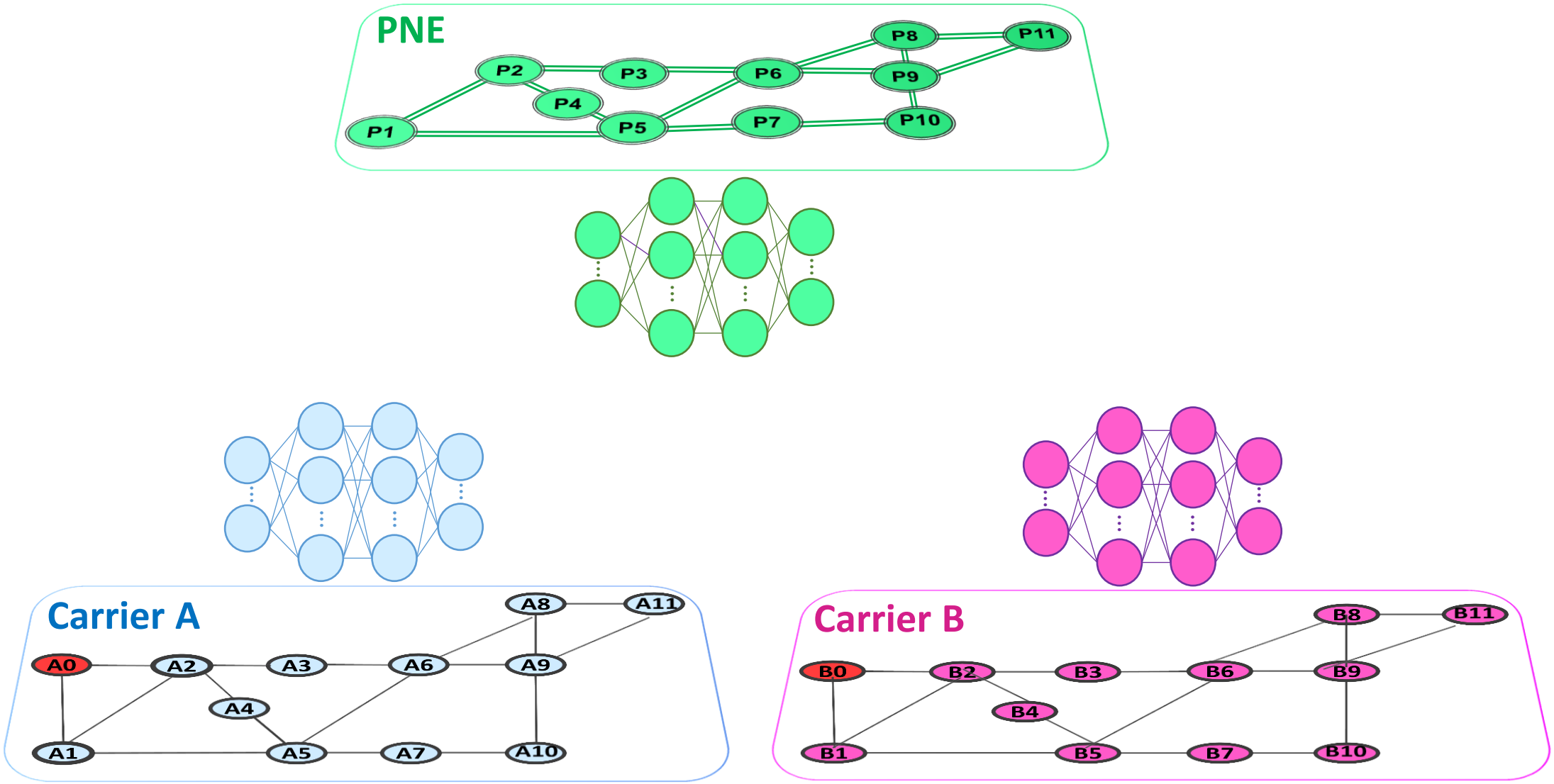


DNN-assisted Model

Phase I: Abstraction and OSNR Estimation



Phase I: Federated Learning-based OSNR Estimation Model



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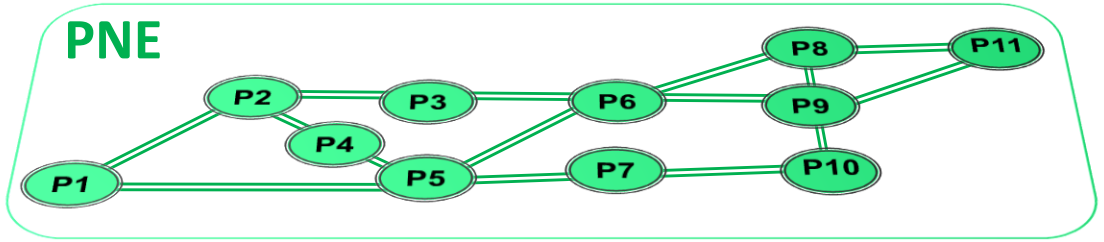
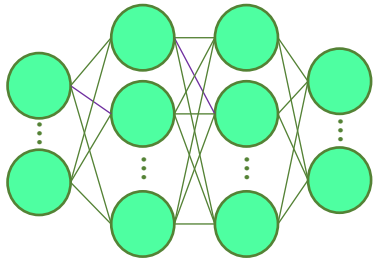
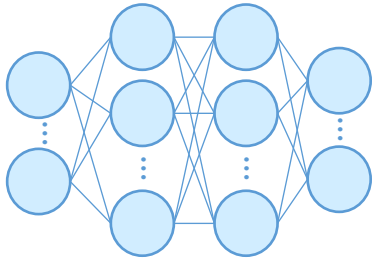
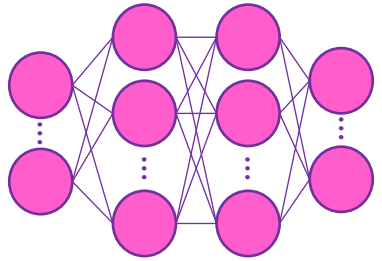
Phase I: Federated Learning-based OSNR Estimation Model

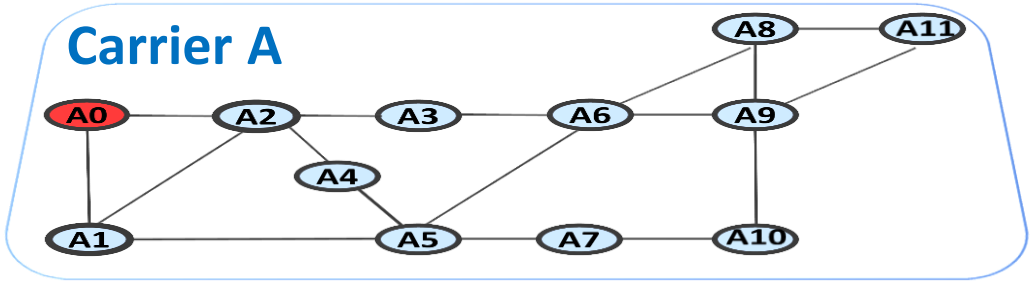


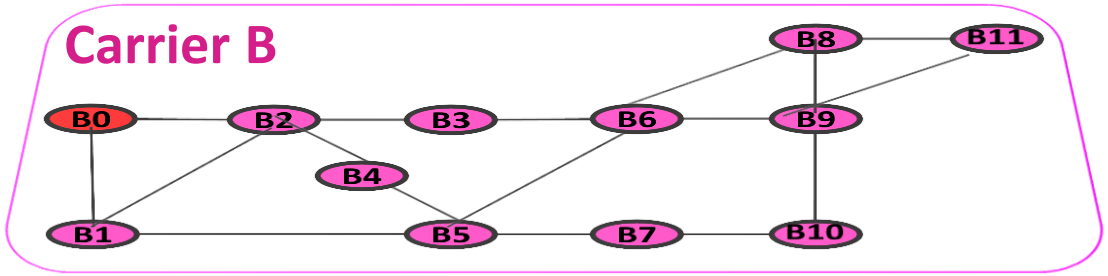


$$\boldsymbol{w} = [w_1, w_2, \ldots, w_n]$$









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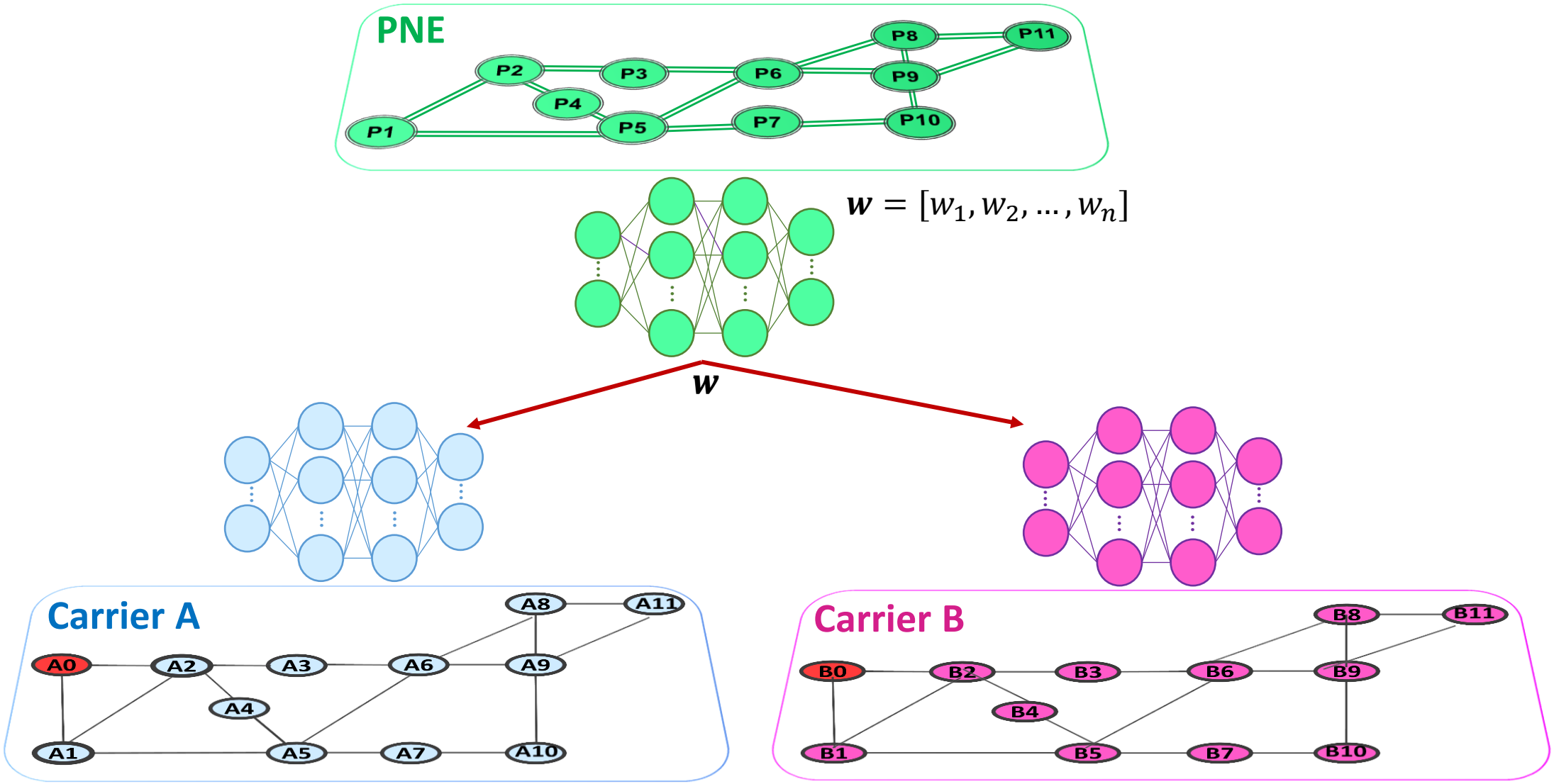
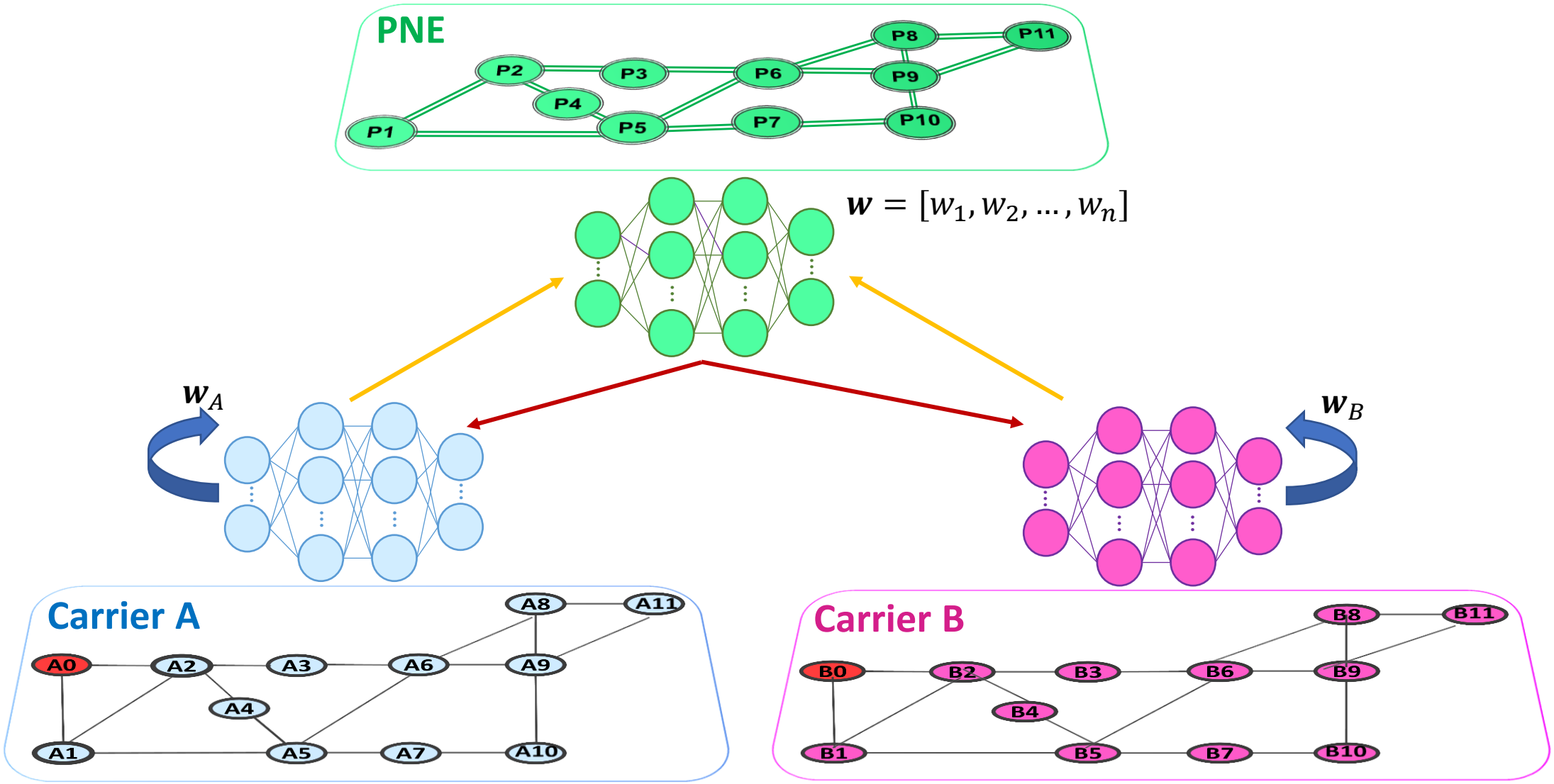
Phase I: Federated Learning-based OSNR Estimation Model



The interconnection between different entities in the ecosystem

Phase I: Federated Learning-based OSNR Estimation Model



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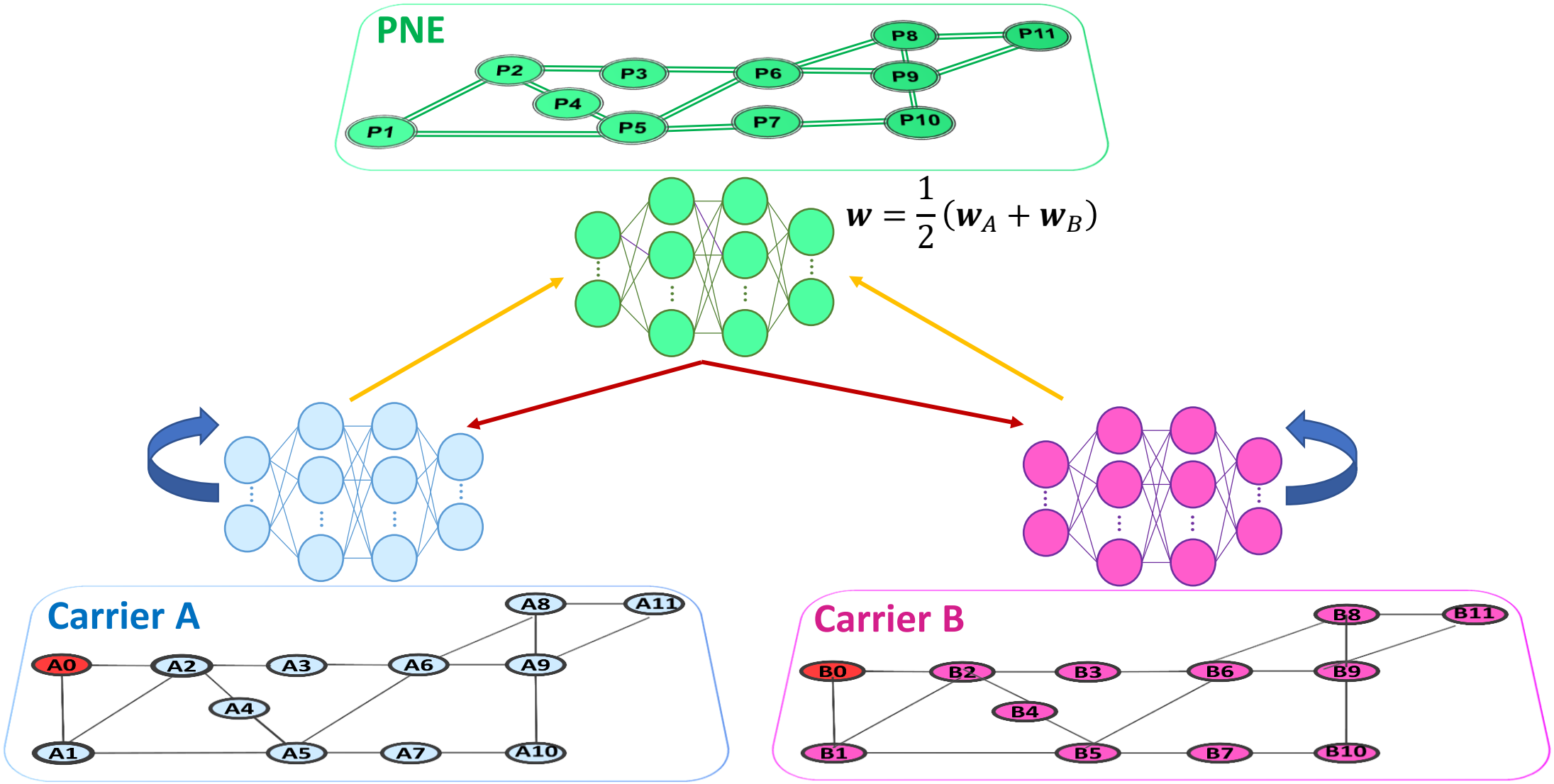
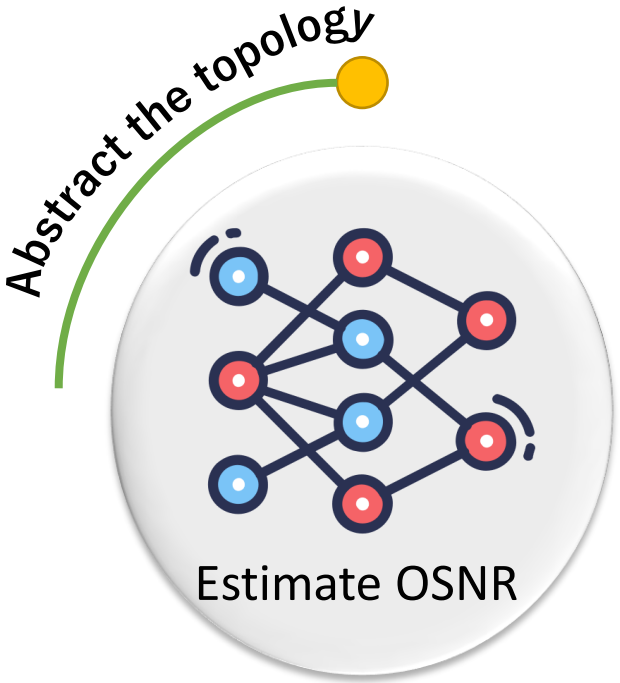


The interconnection between different entities in the ecosystem

Flow of The Proposed Framework



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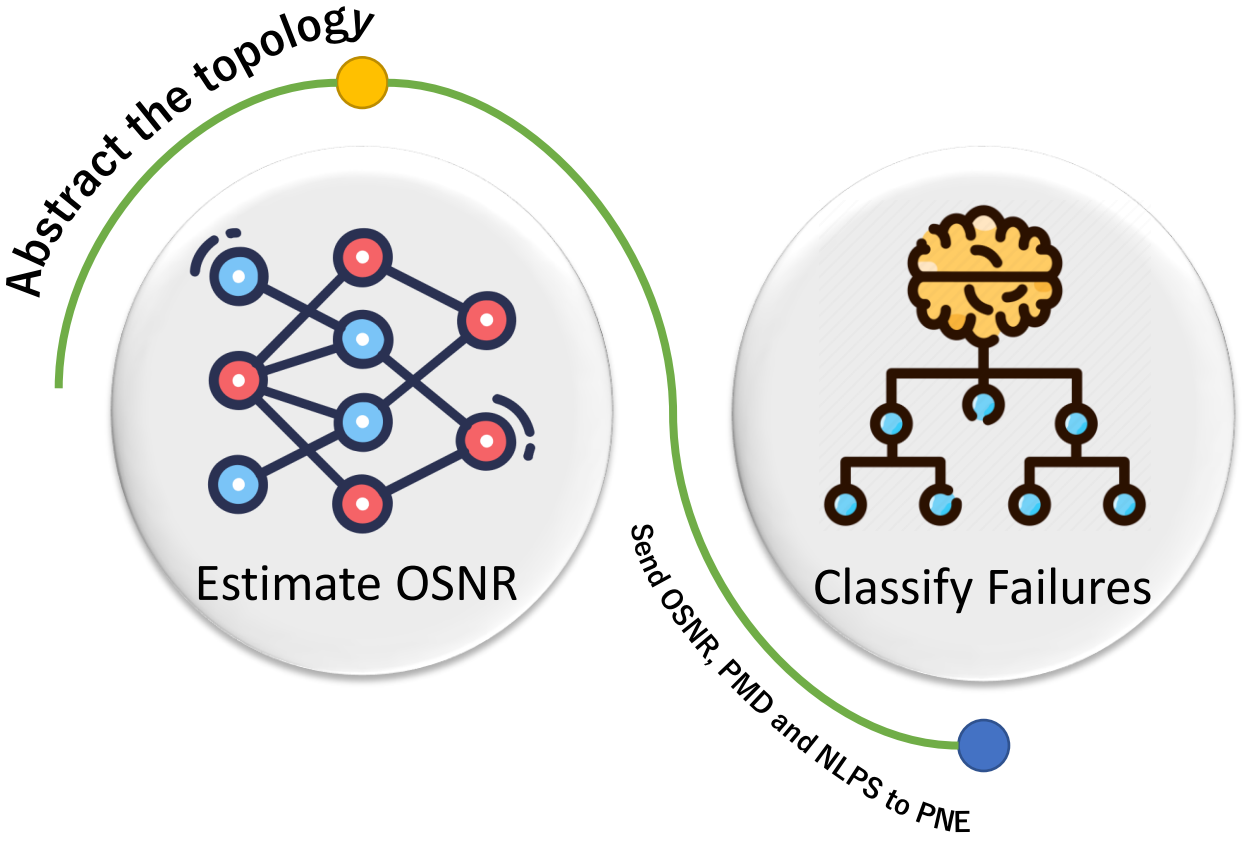

Phase II: Classification

Danshi Wang, Chunyu Zhang, Wenbin Chen, Hui Yang, Min Zhang & Alan Pak Tao Lau, “A review of machine learning-based failure management in optical networks,” in *Science China Information Sciences*, vol. 65, no. 211302, 2022.

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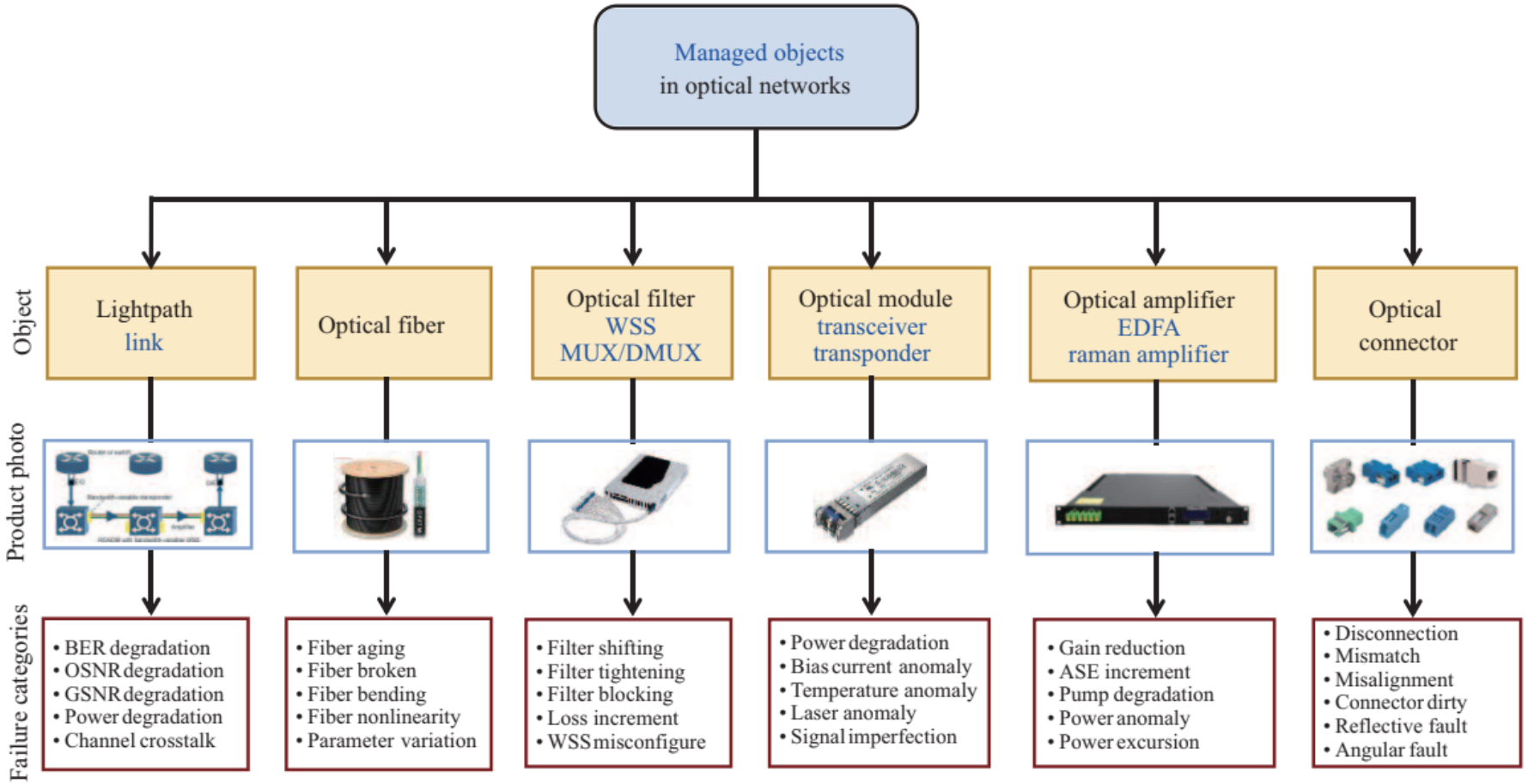

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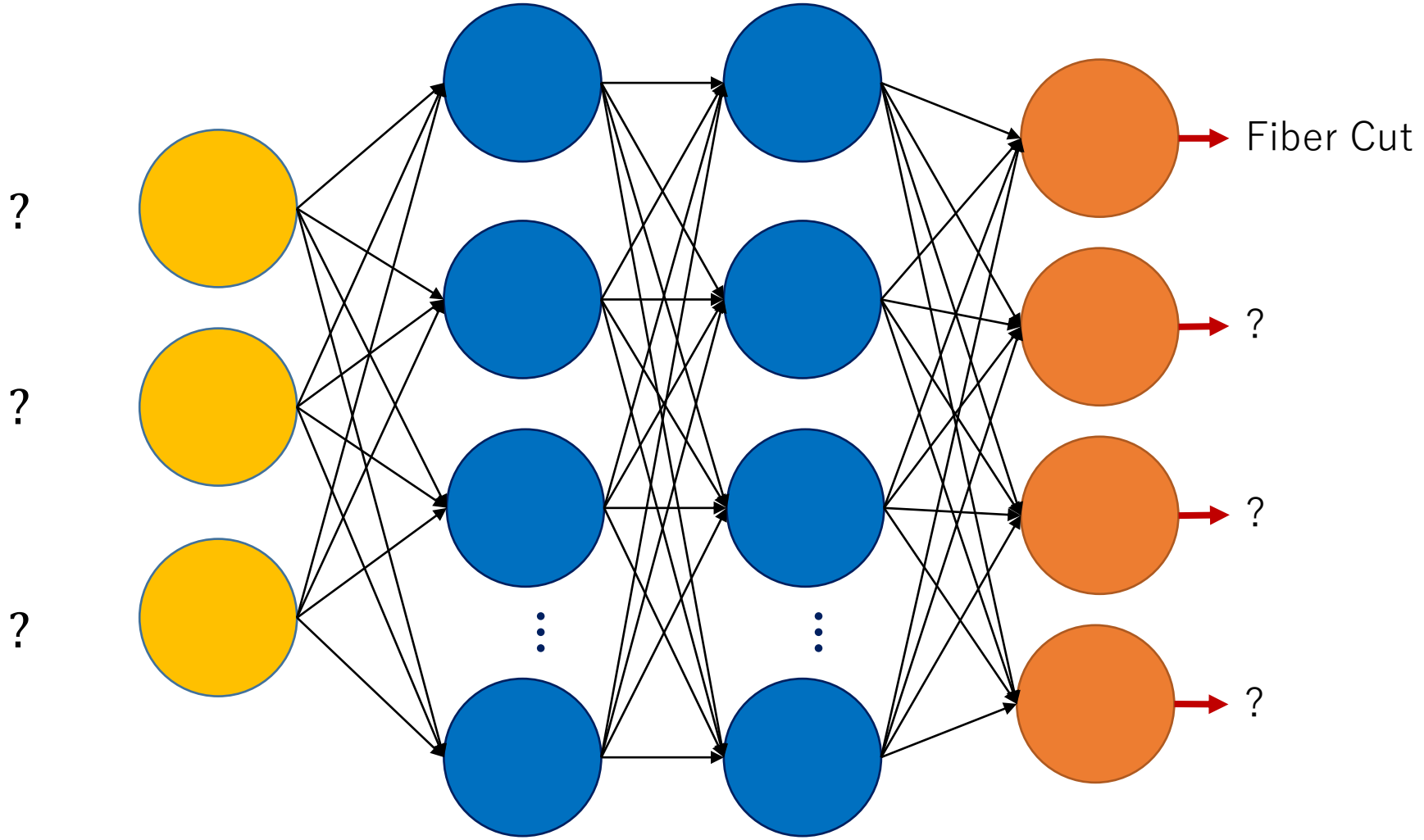

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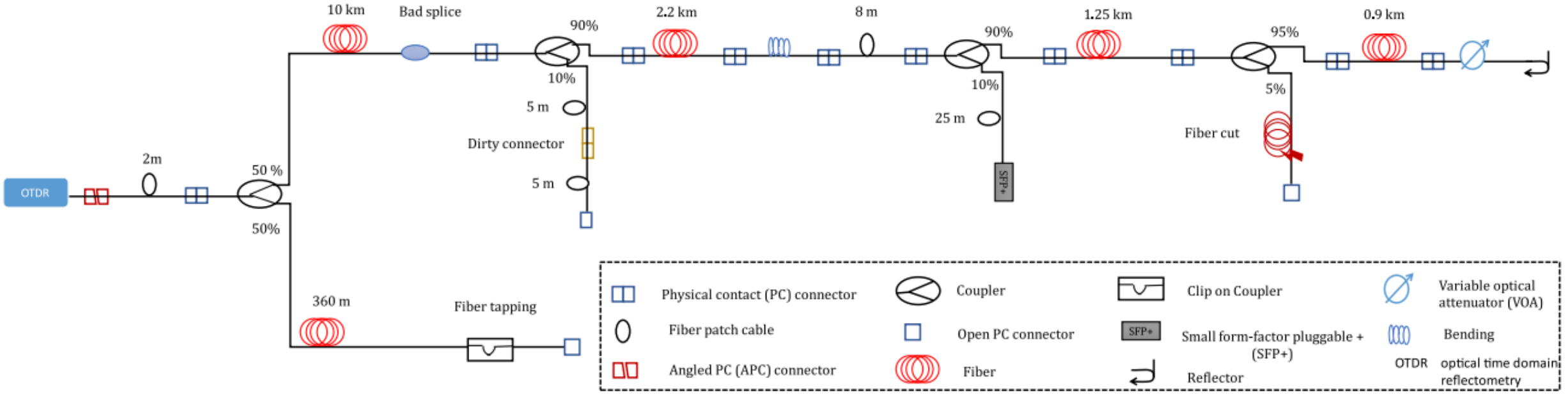

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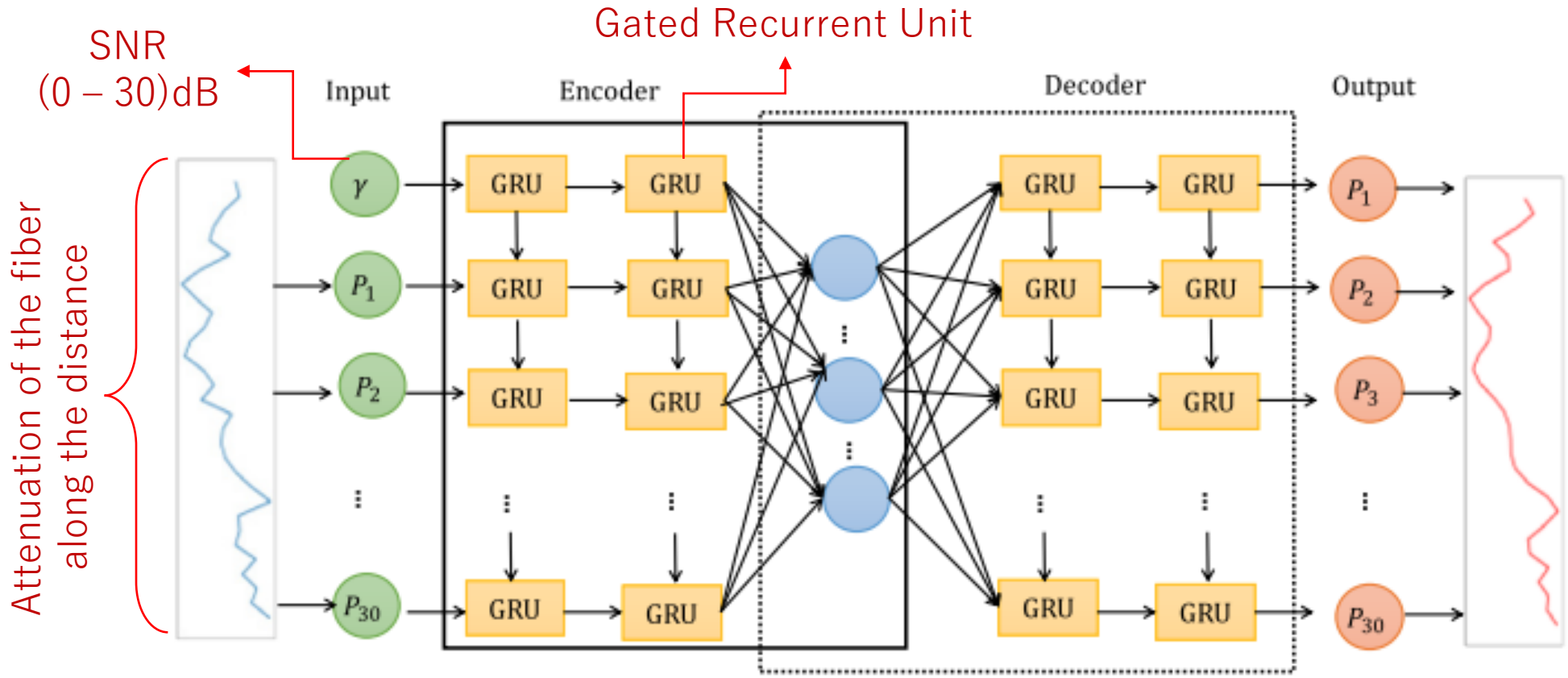

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0	1	2	3	4	5	6	7
Normal	Fiber Tapping	Bad Splice	Bending Event	Dirty Connector	Fiber Cut	PC Connector	Reflector

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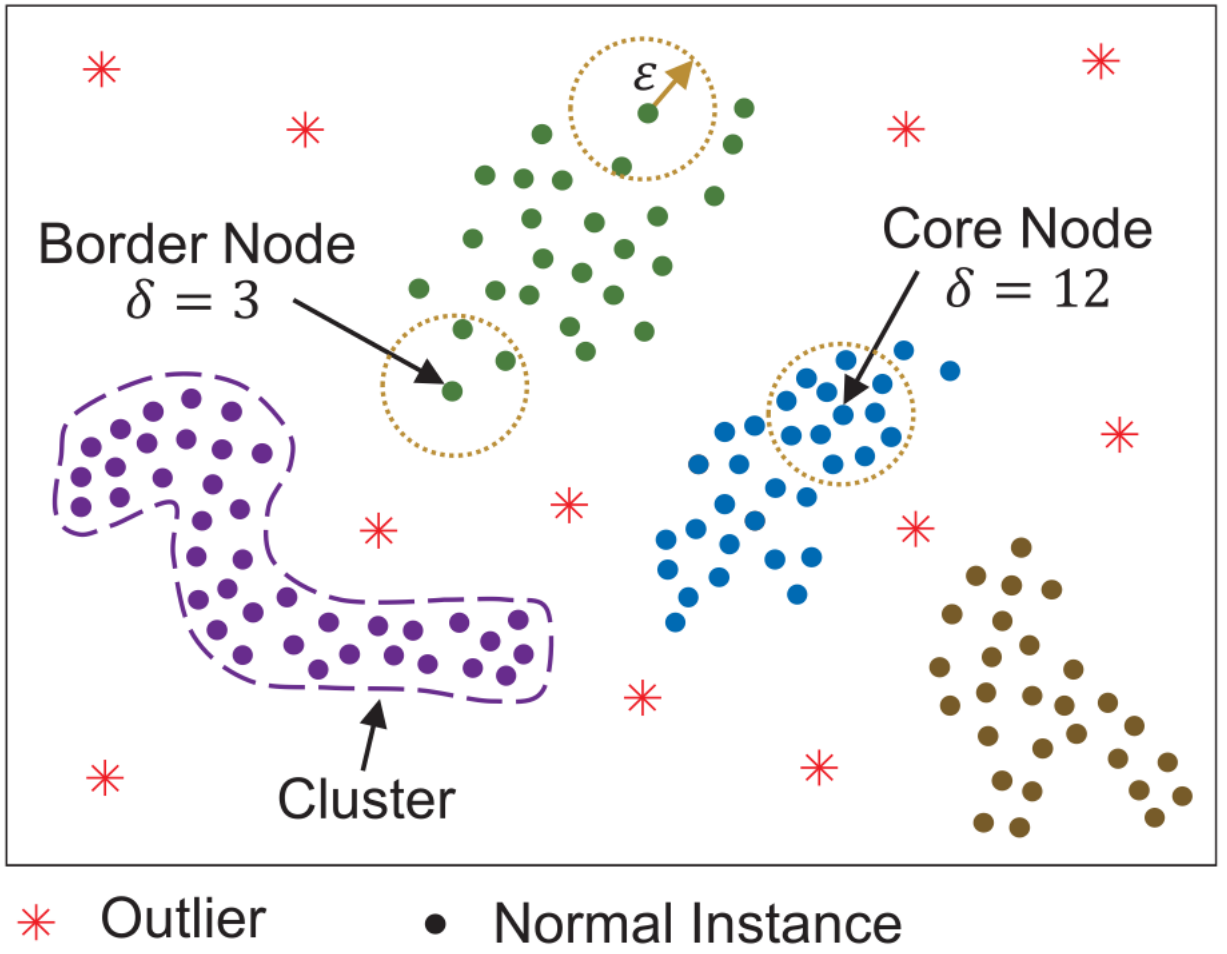

X. Chen, B. Li, R. Proietti, Z. Zhu and S. J. B. Yoo, "Self-Taught Anomaly Detection With Hybrid Unsupervised/Supervised Machine Learning in Optical Networks," in Journal of Lightwave Technology, vol. 37, no. 7, pp. 1742-1749, 1 April1, 2019.

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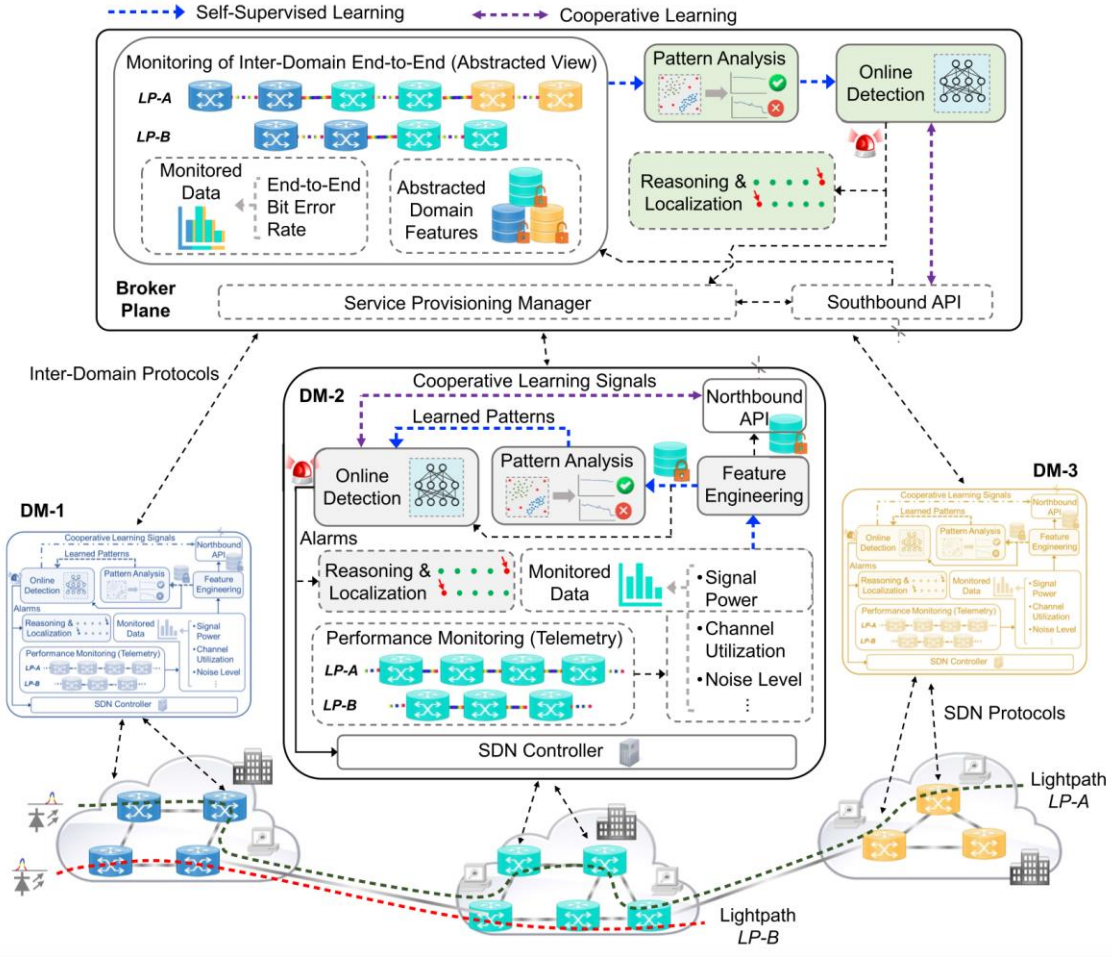

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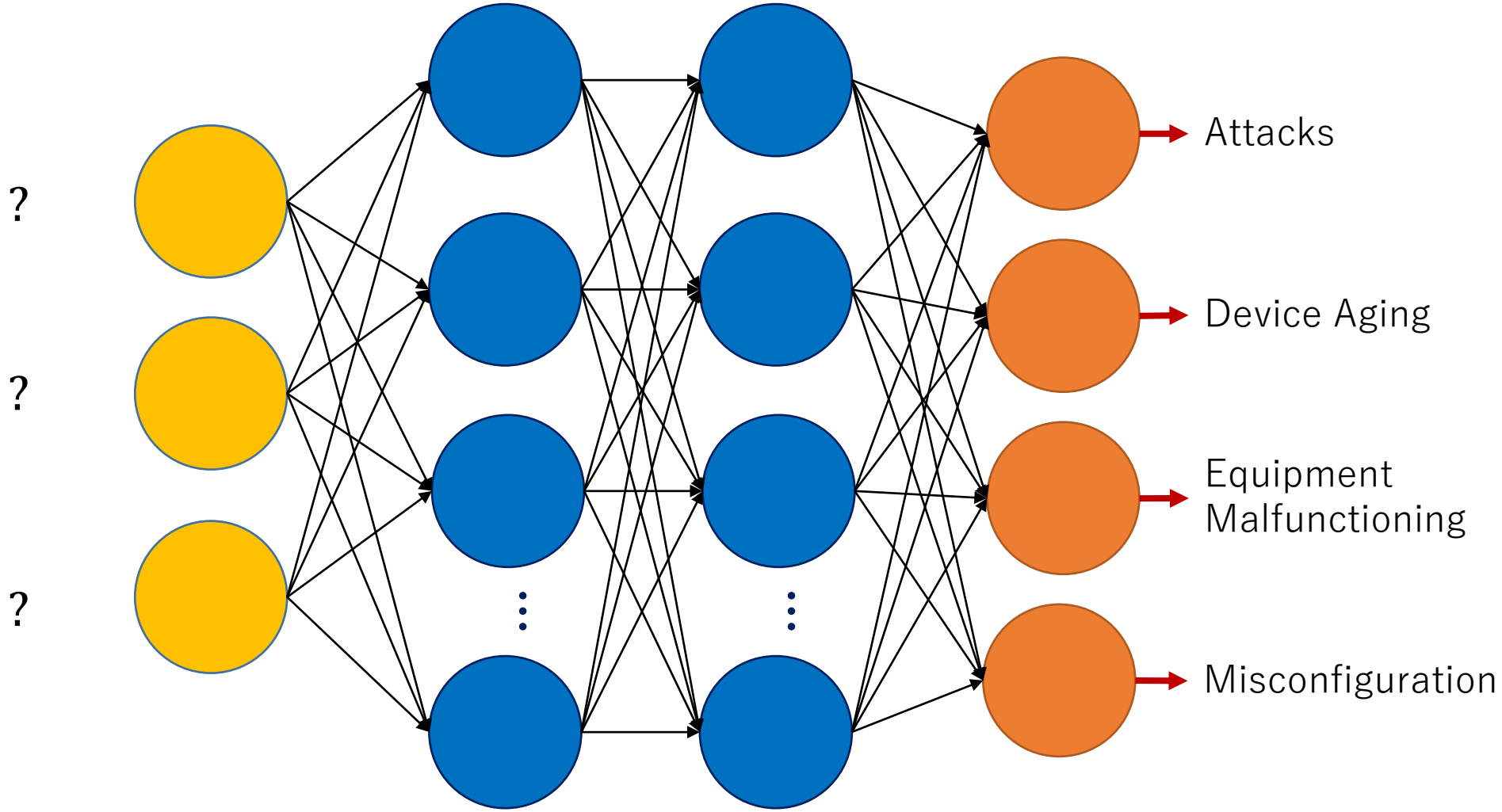
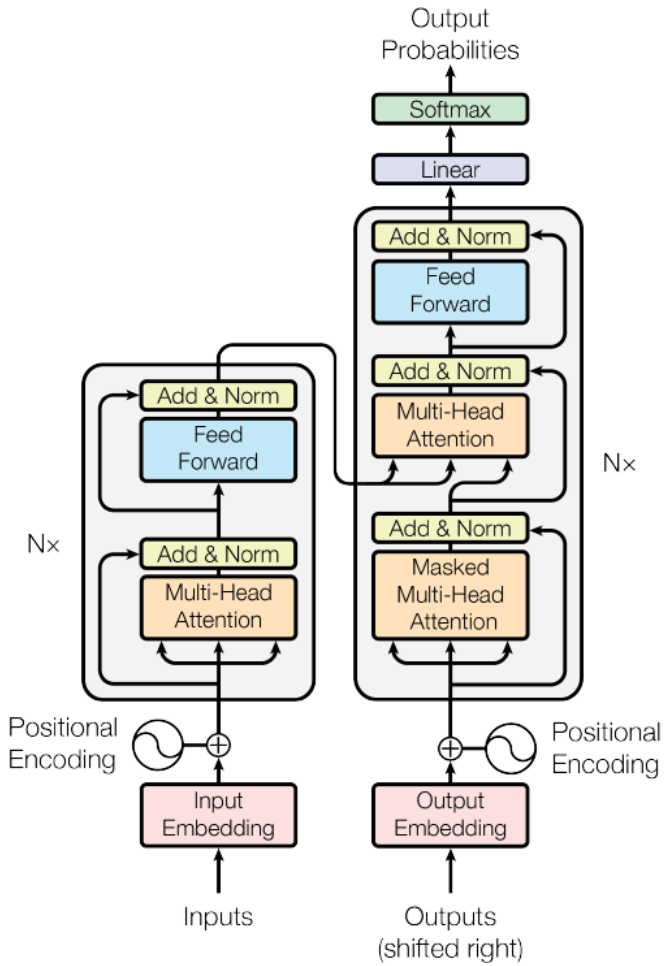


Phase II: Transformer Neural Networks



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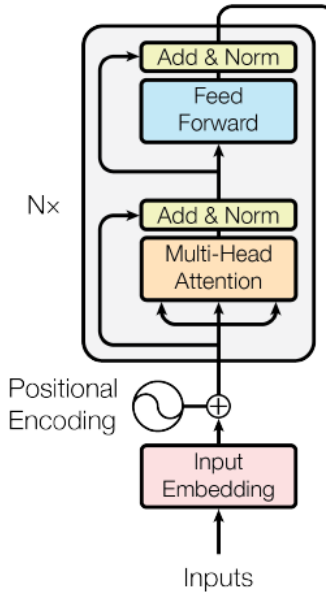

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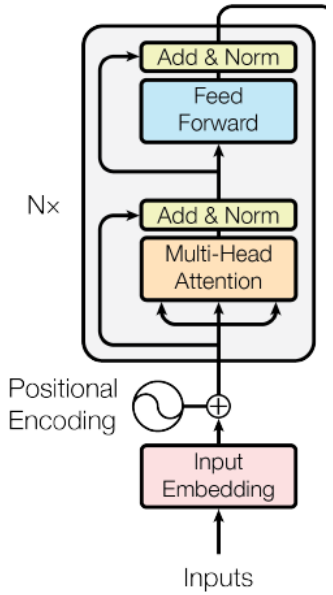
Phase II: Transformer Neural Networks

Bark is very cute and he is a dog



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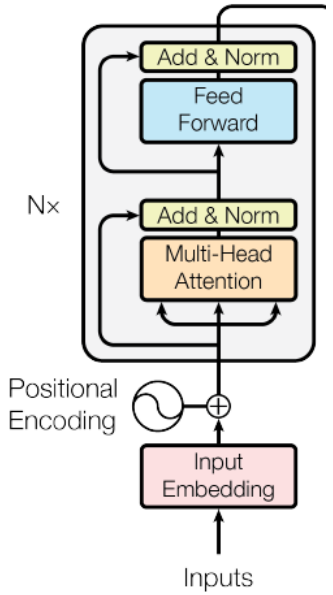

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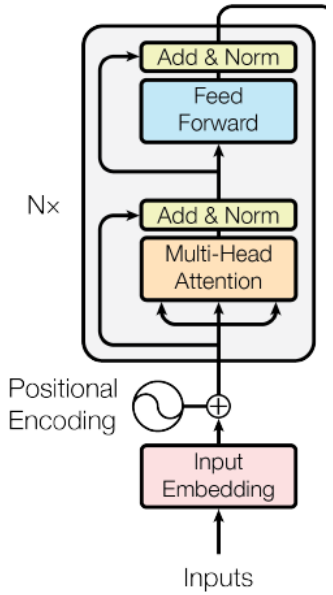

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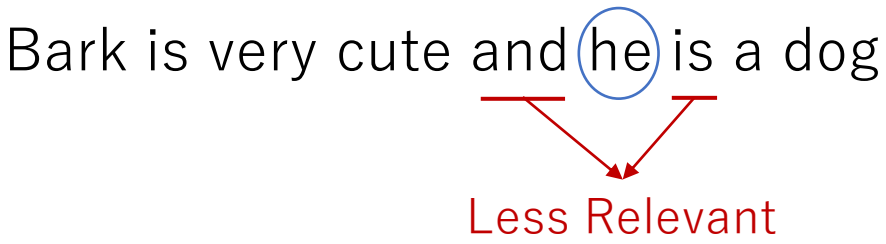

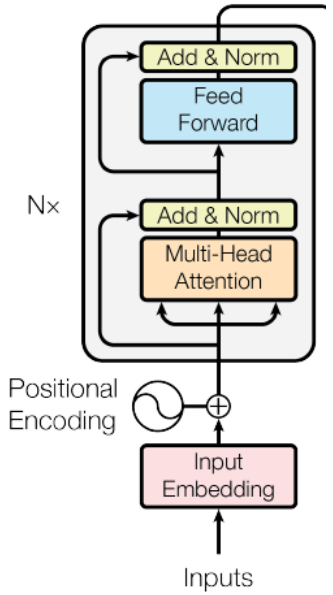

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Phase II: Transformer Neural Networks

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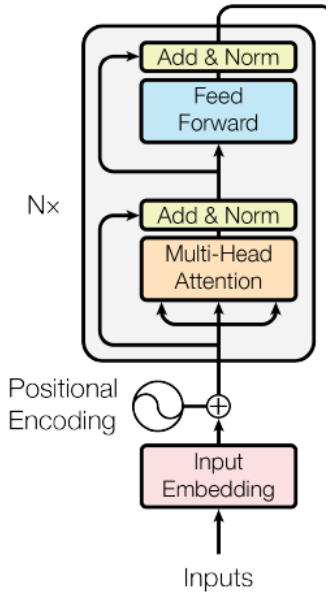
Less Relevant



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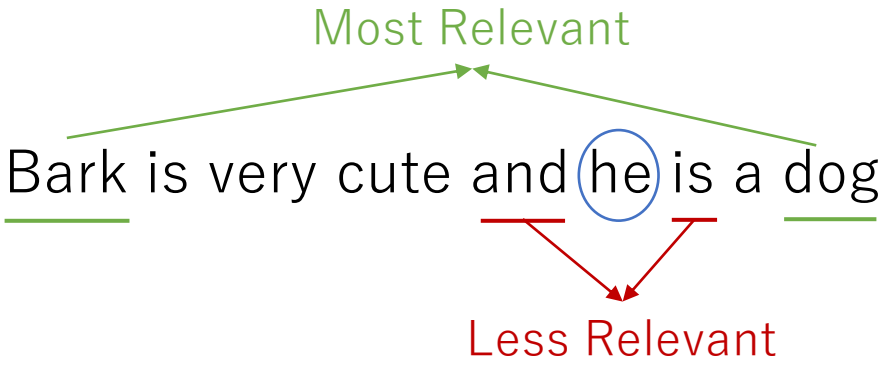

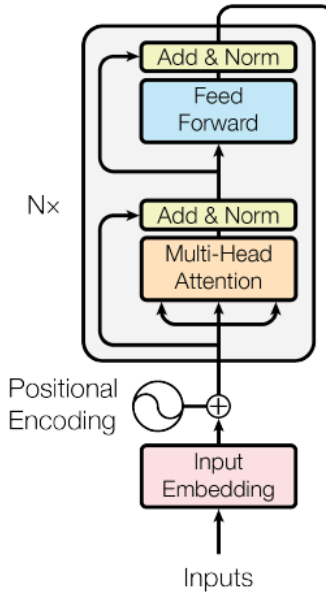

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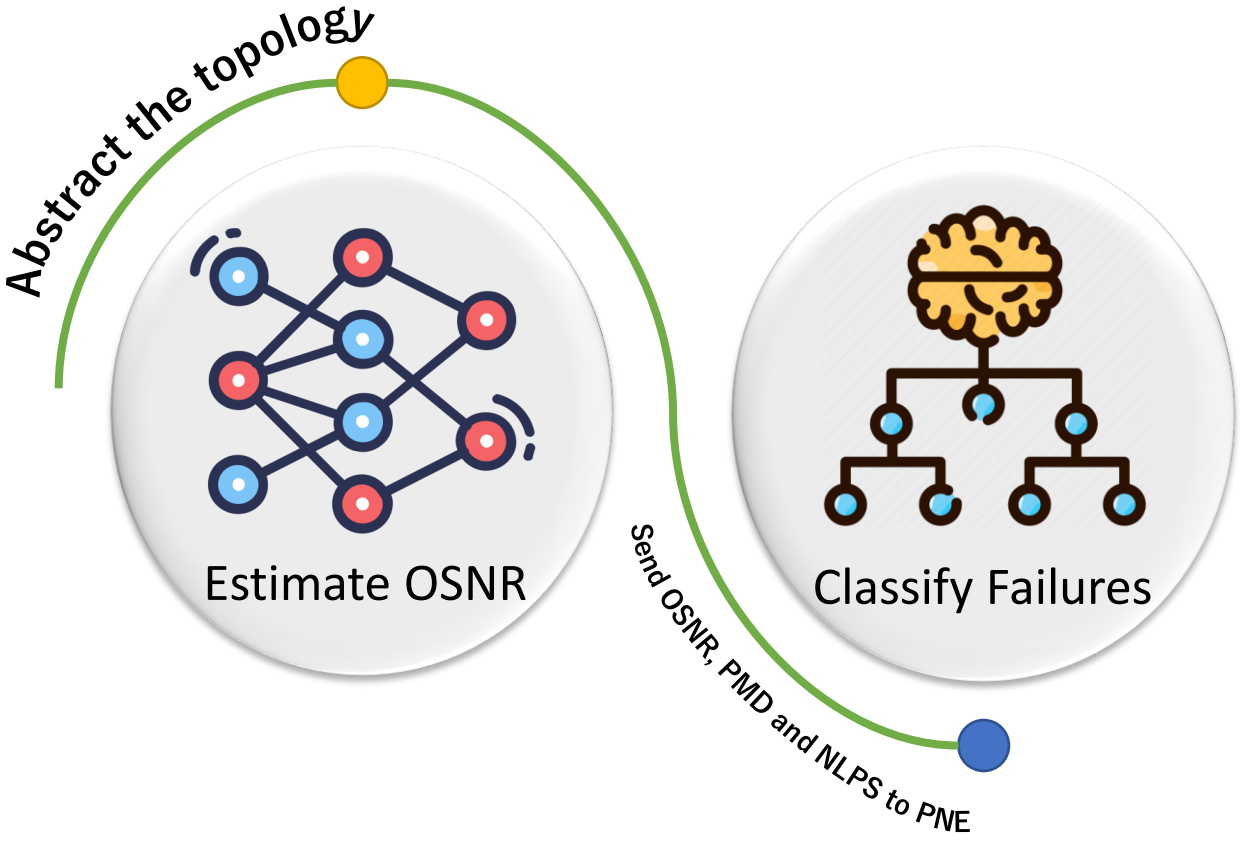
Flow of The Proposed Framework



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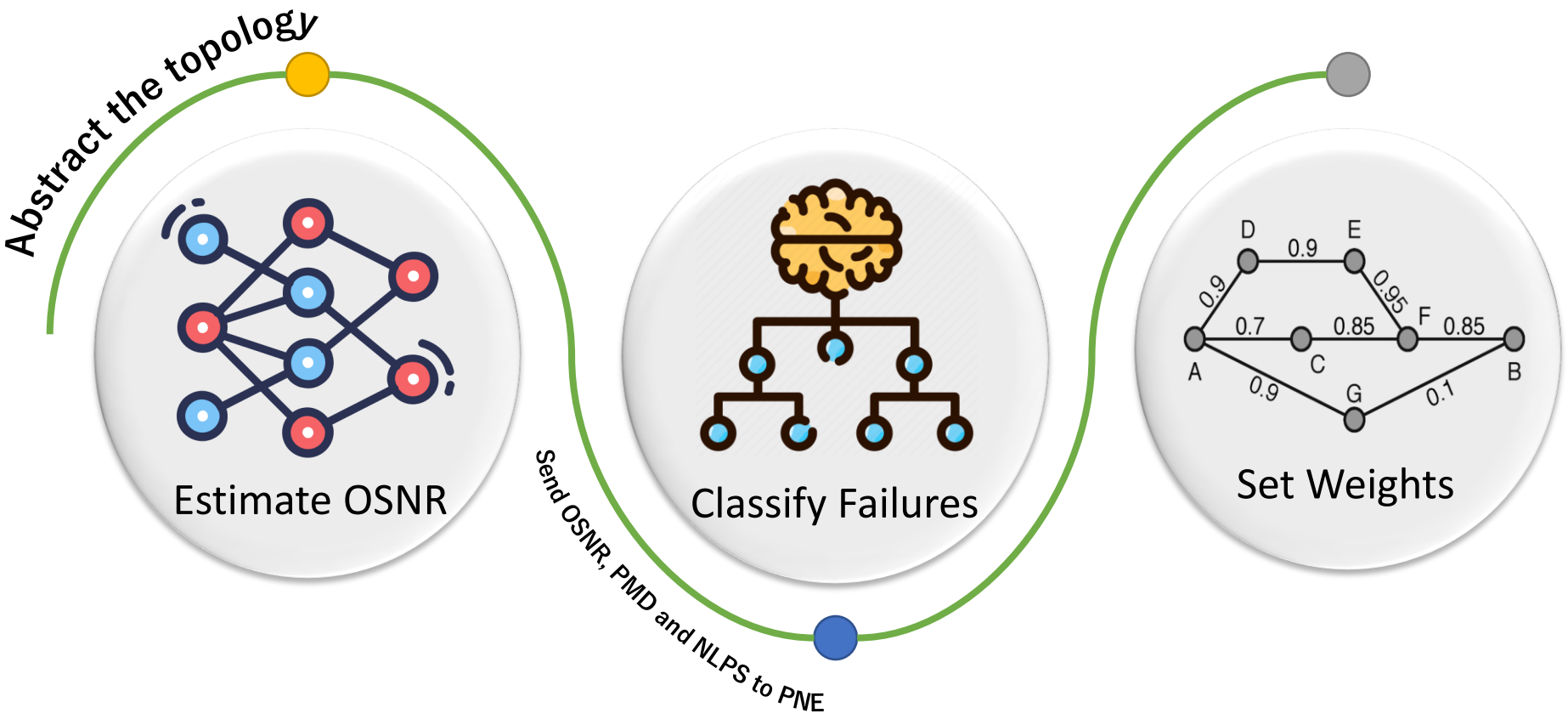
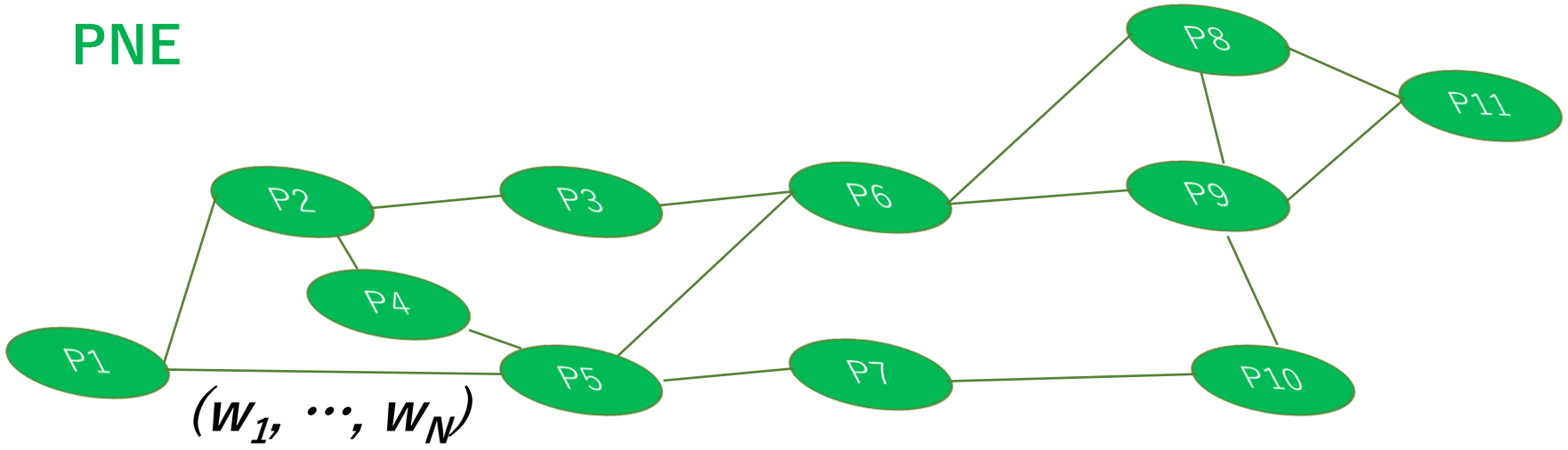
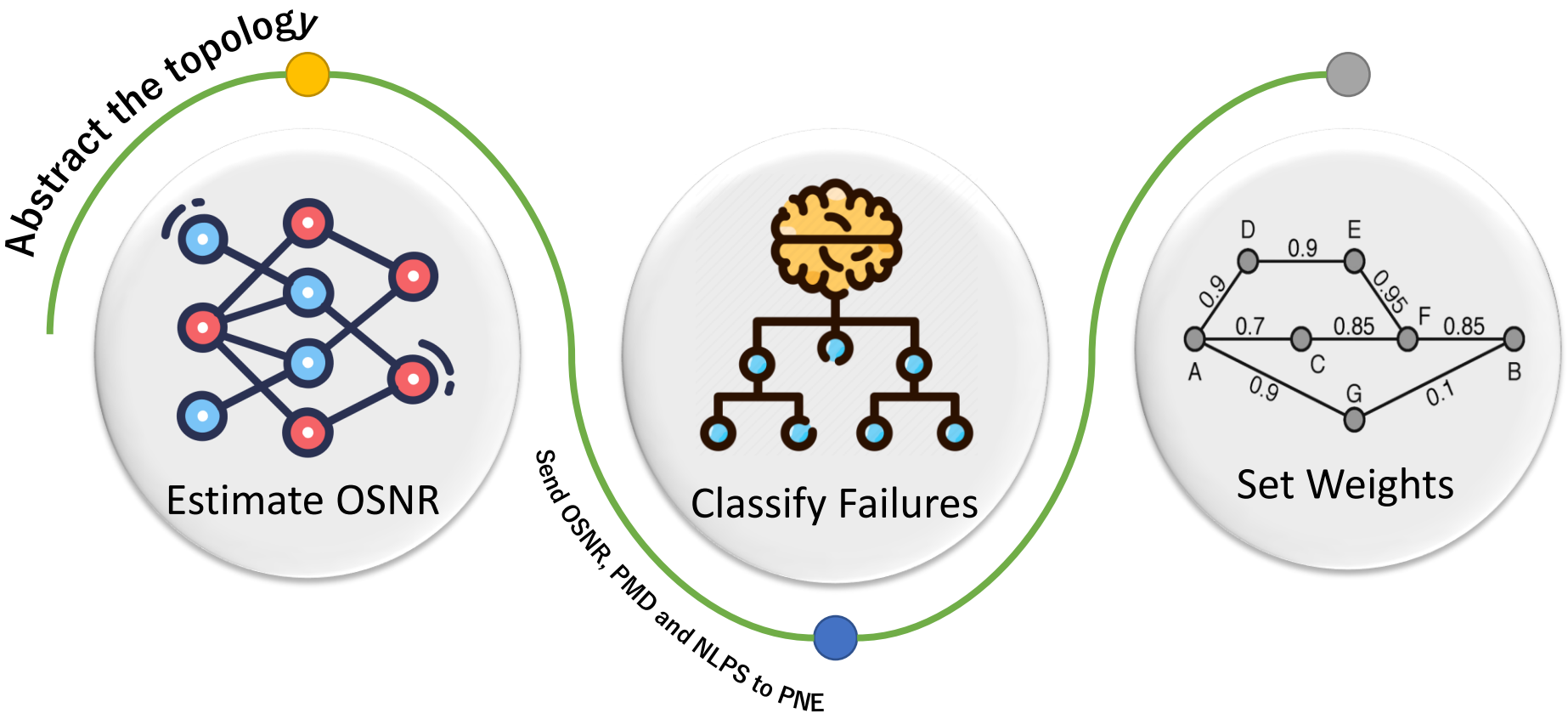


Setting Weights



Link	Weight	Link	Weight	Link	Weight	Link	Weight
(P1-P2)	$(w_1, \cdots, w_N)$	(P3-P6)	$(w_1, \cdots, w_N)$	(P6-P8)	$(w_1, \cdots, w_N)$	(P8-P11)	$(w_1, \cdots, w_N)$
(P1-P5)	$(w_1, \cdots, w_N)$	(P4-P5)	$(w_1, \cdots, w_N)$	(P6-P9)	$(w_1, \cdots, w_N)$	(P9-P10)	$(w_1, \cdots, w_N)$
(P2-P3)	$(w_1, \cdots, w_N)$	(P5-P6)	$(w_1, \cdots, w_N)$	(P7-P10)	$(w_1, \cdots, w_N)$	(P9-P11)	$(w_1, \cdots, w_N)$
(P2-P4)	$(w_1, \cdots, w_N)$	(P5-P7)	$(w_1, \cdots, w_N)$	(P8-P9)	$(w_1, \cdots, w_N)$		

Flow of The Proposed Framework



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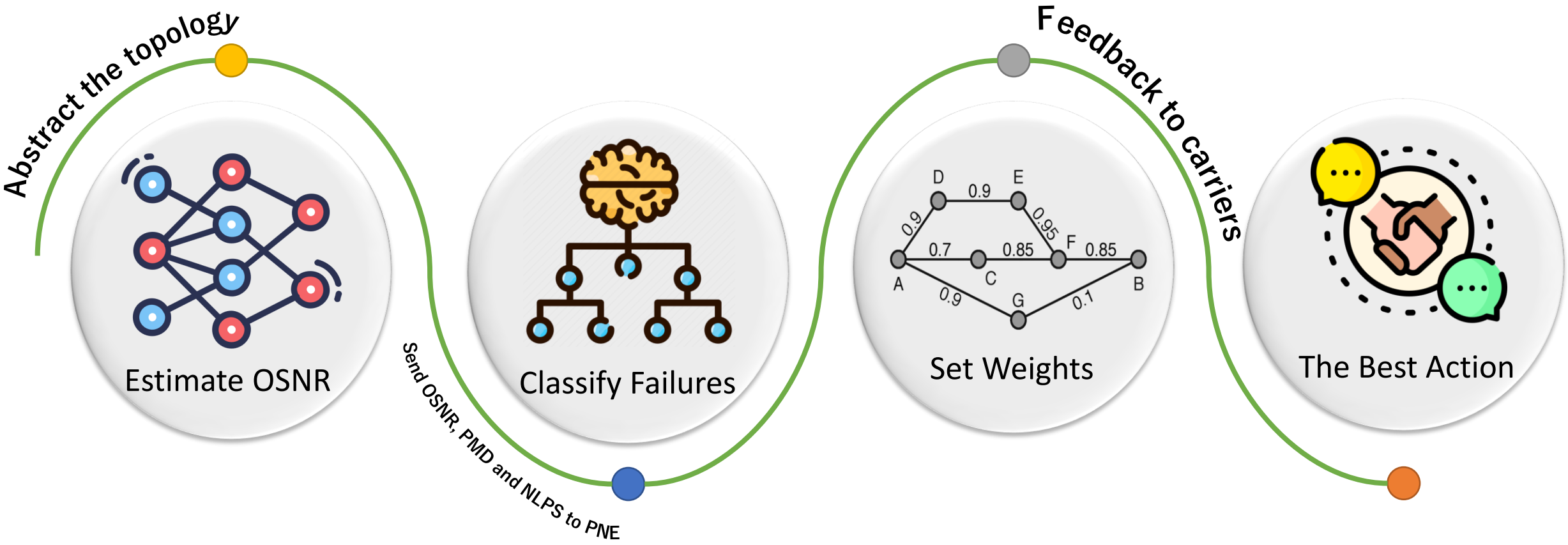

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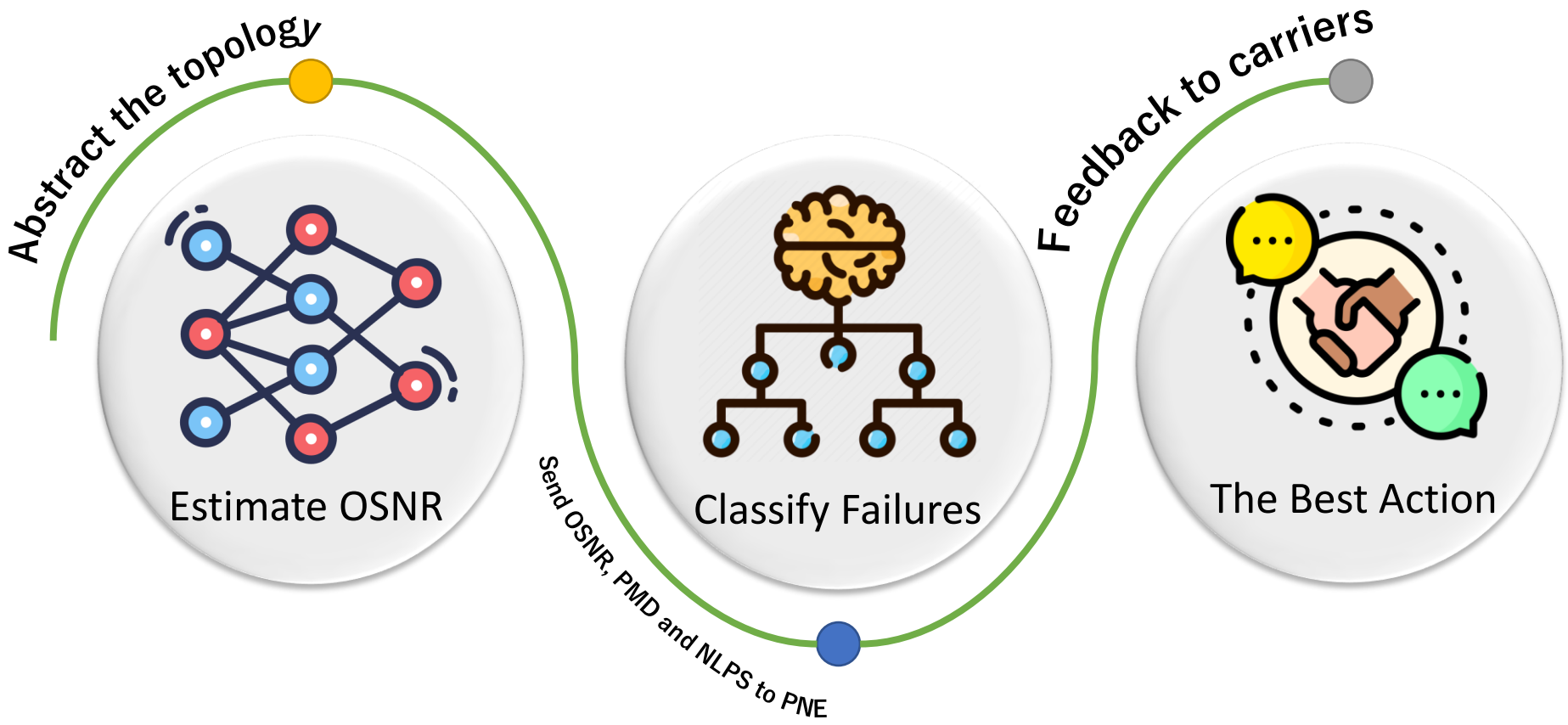

The interconnection between different entities in the ecosystem

Phase III: Providing Carriers with Suggestions

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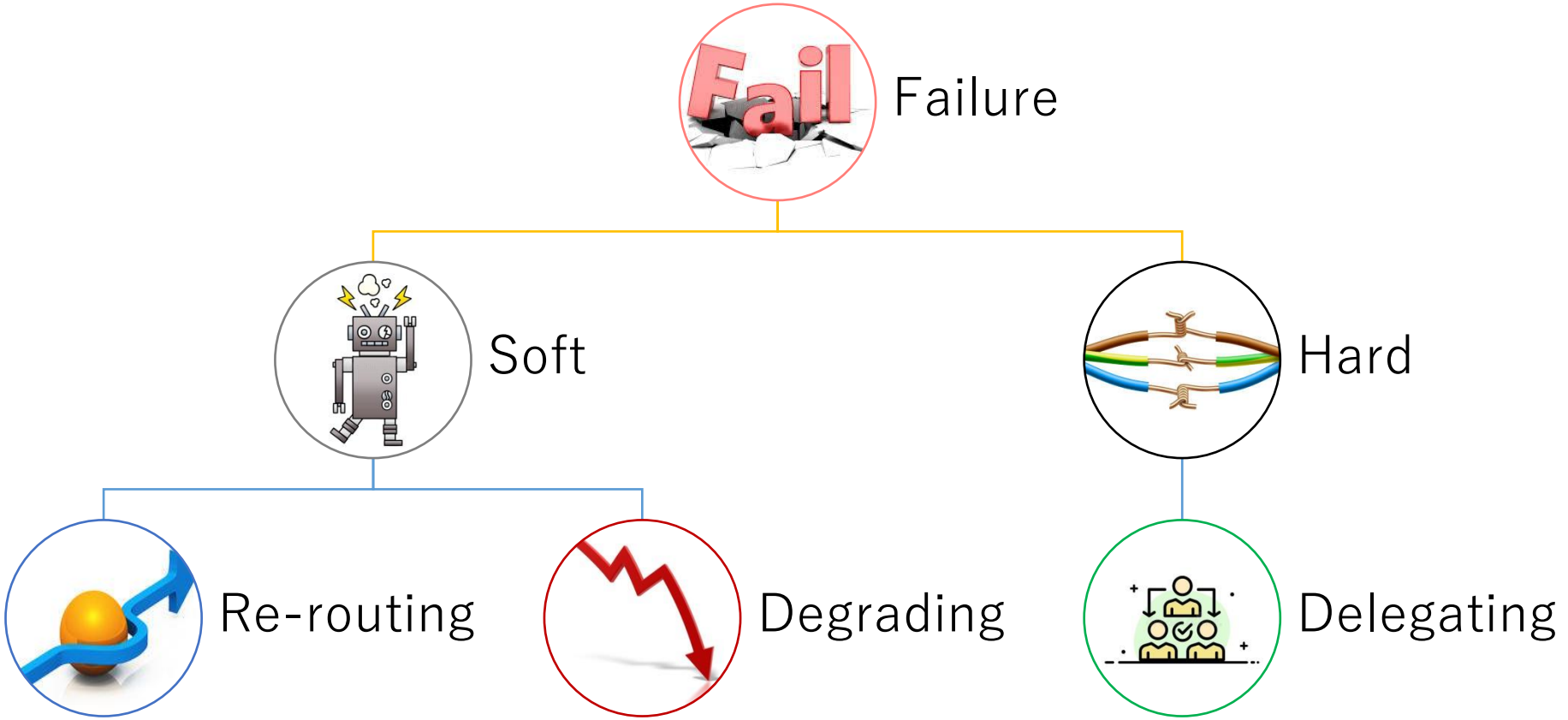

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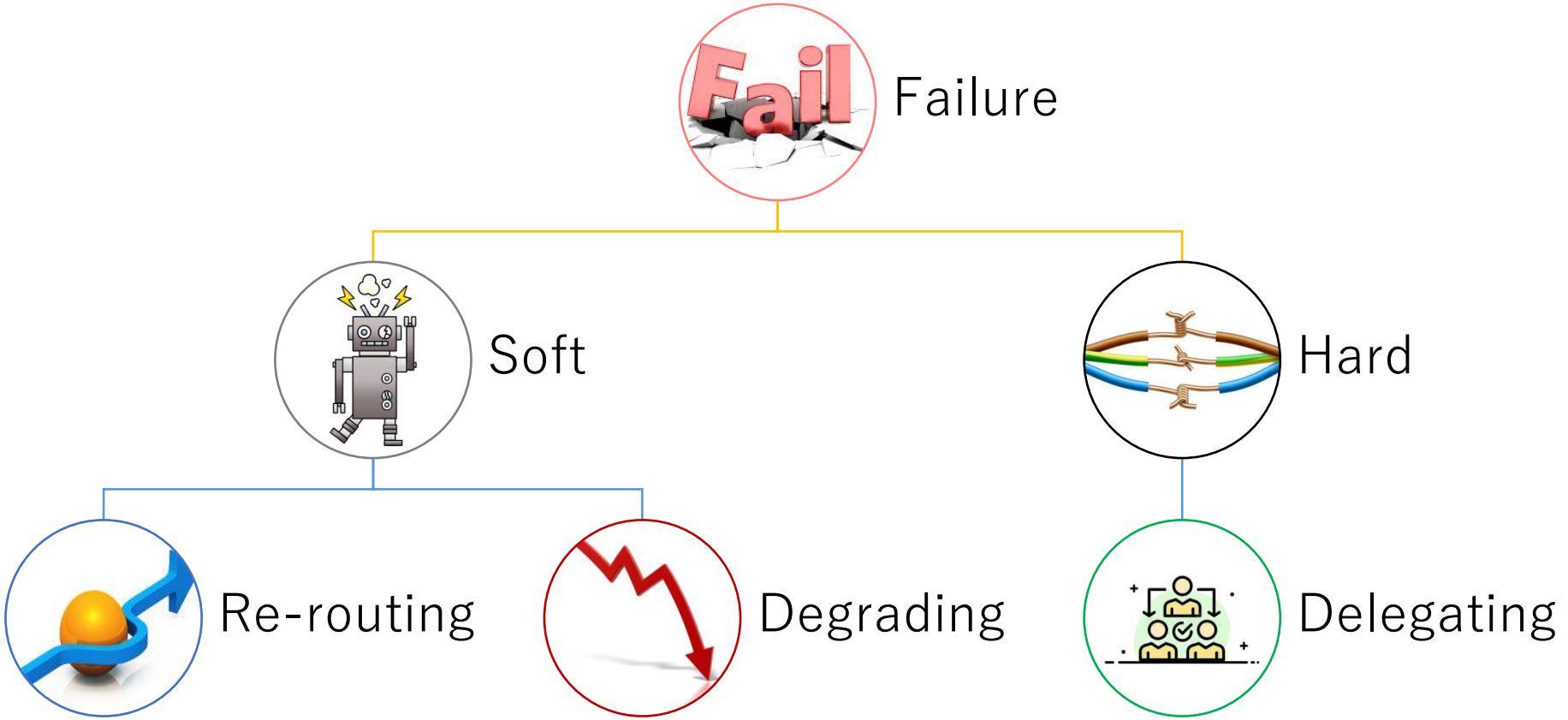

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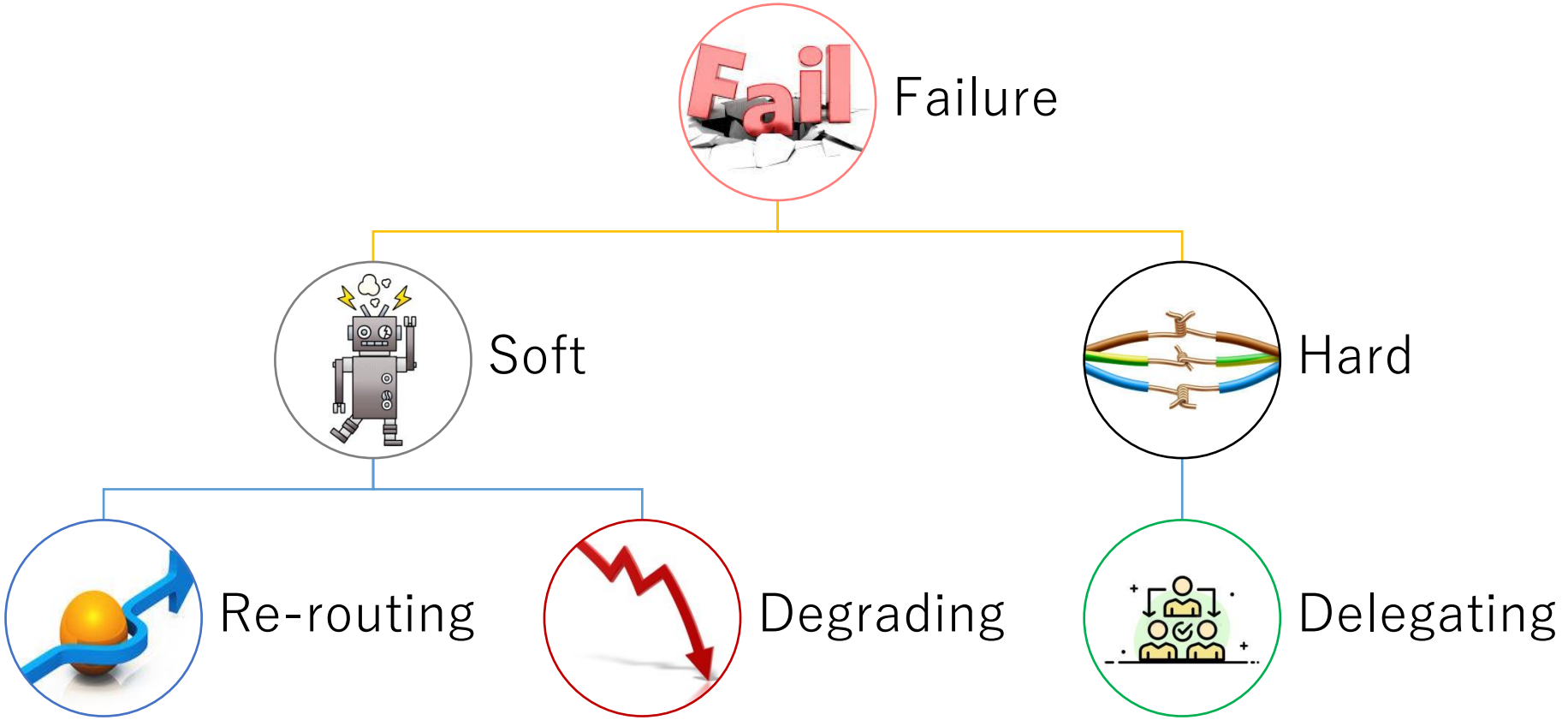

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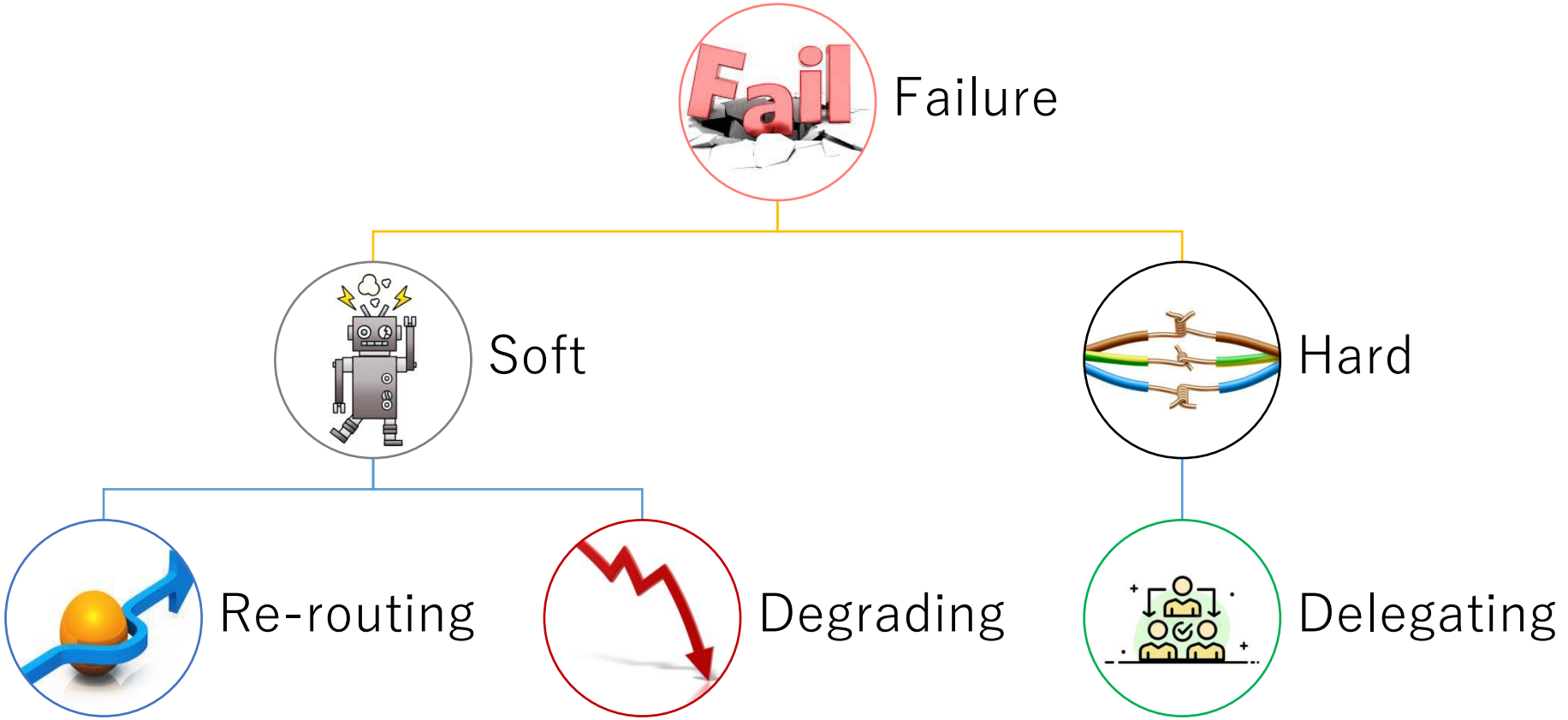

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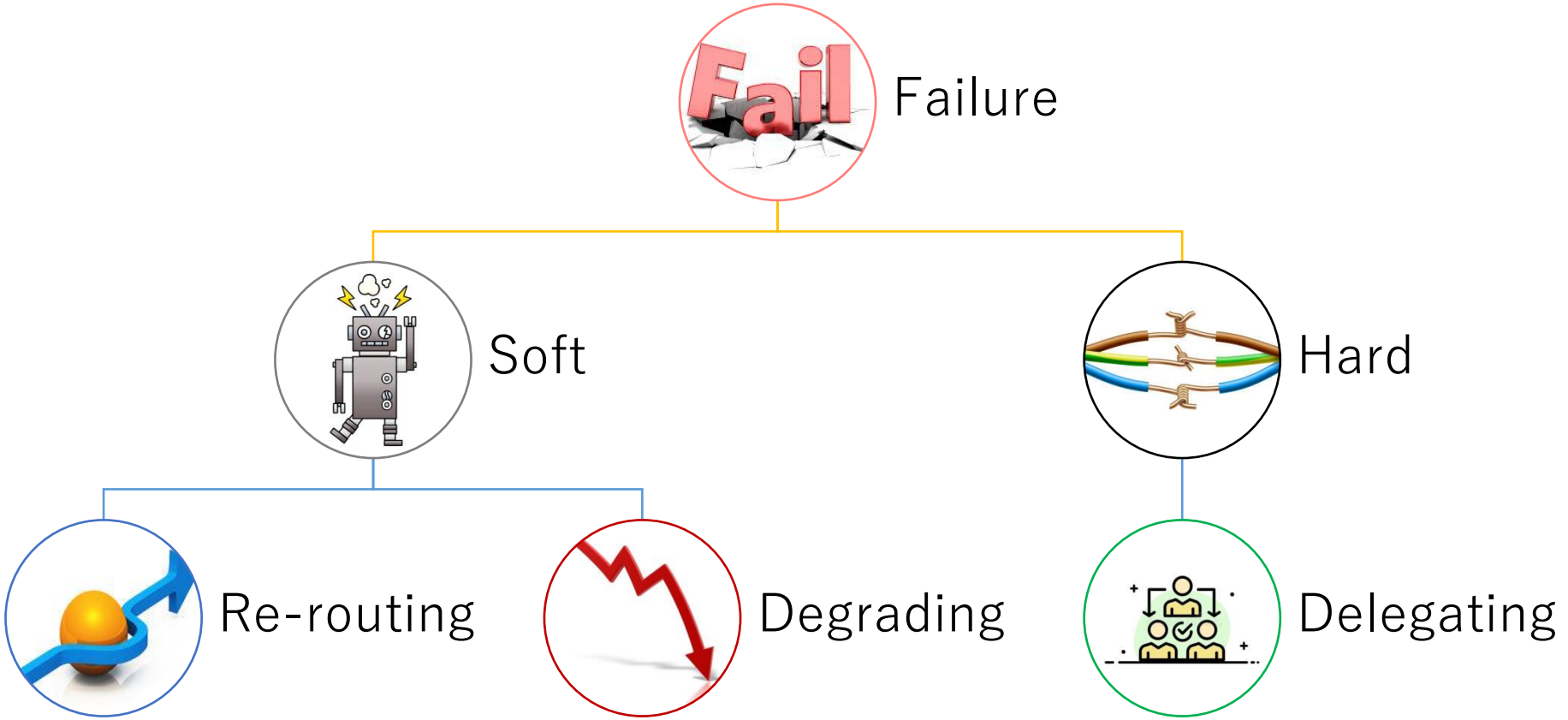

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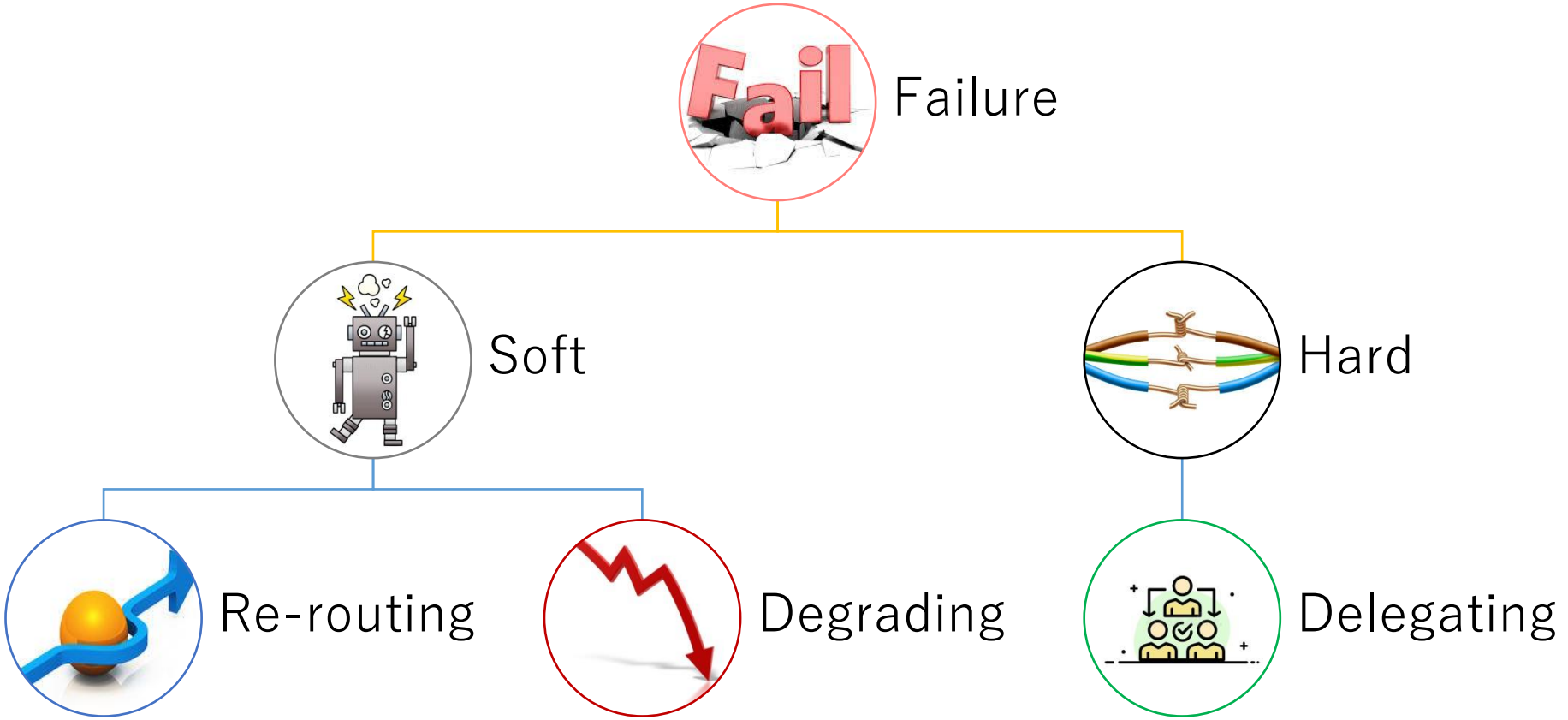

Phase III: Negotiation

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PNE	Carrier	DCP	ISP
• Enhance ecosystem survivability • Prolong ecosystem lifetime • Optimal resource management	• Reduce burden (resource crunch) • Reduce recovery cost	• Lower cost • Higher service restoration	• Lower cost • Higher service restoration

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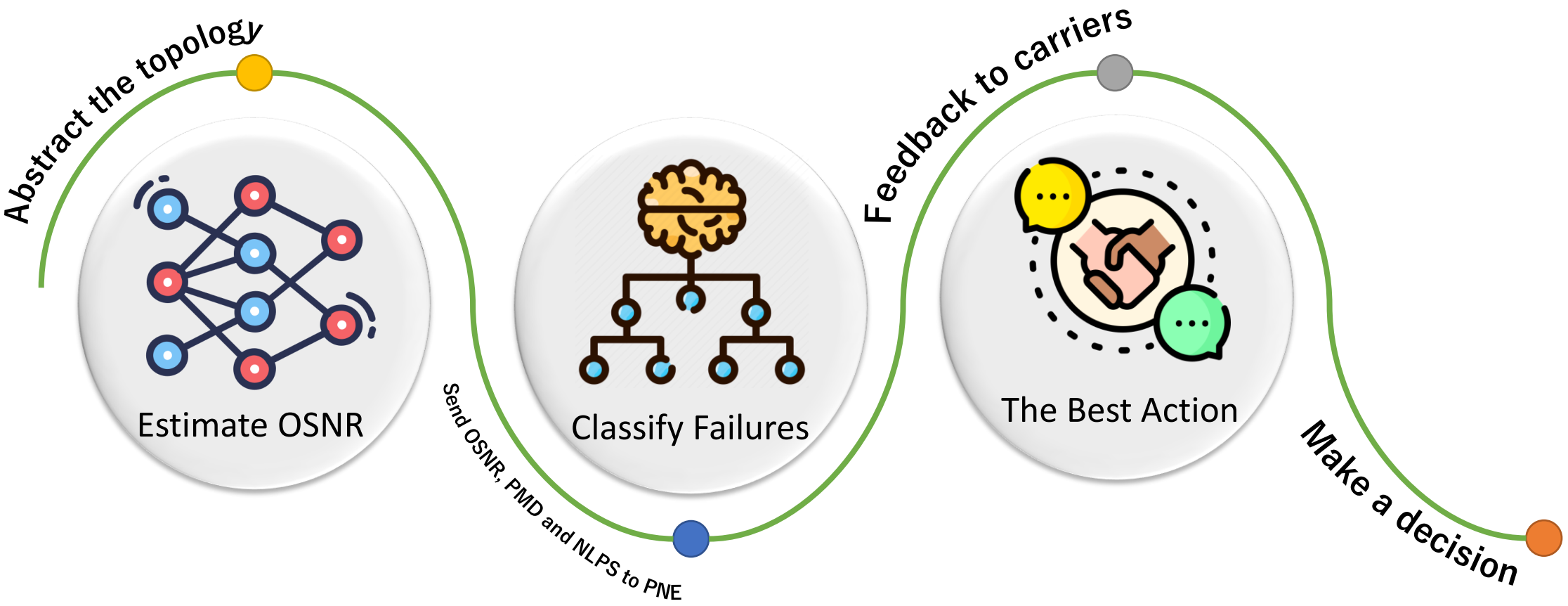
Flow of The Proposed Framework

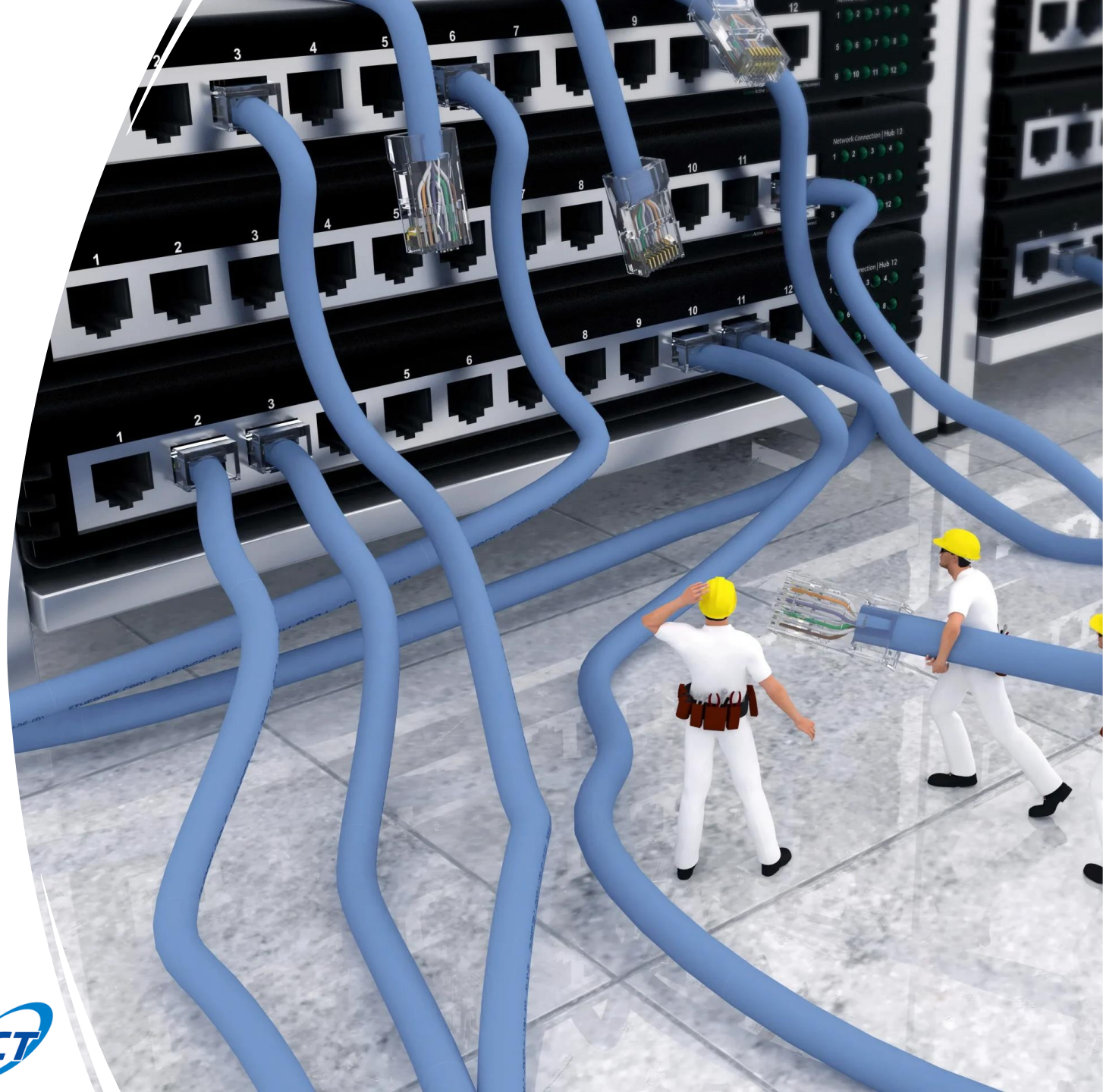


Task 4: Preemptive and Early Failure Detection and Management

July 28, 2023

Presented by:

Forough Shirin Abkenar



General System Architecture

The interconnection between different entities in the ecosystem

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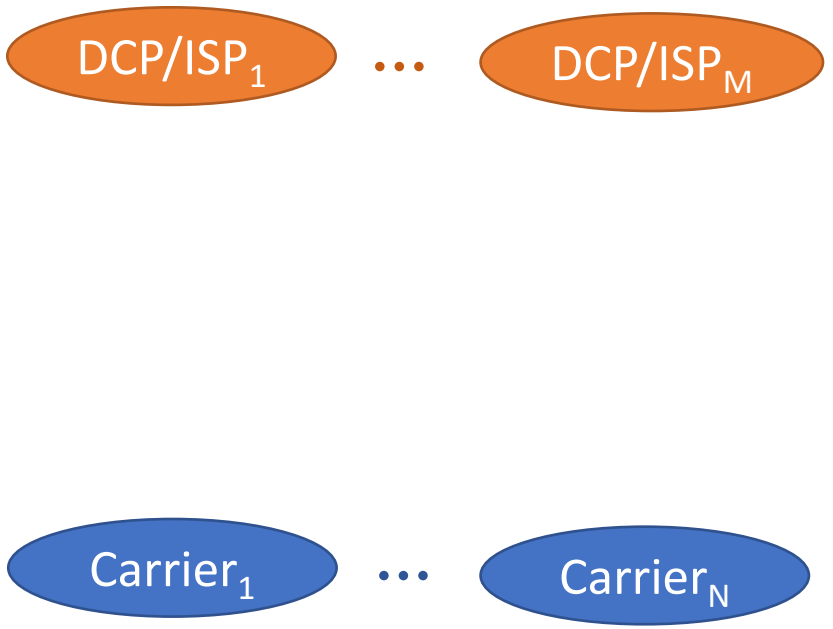

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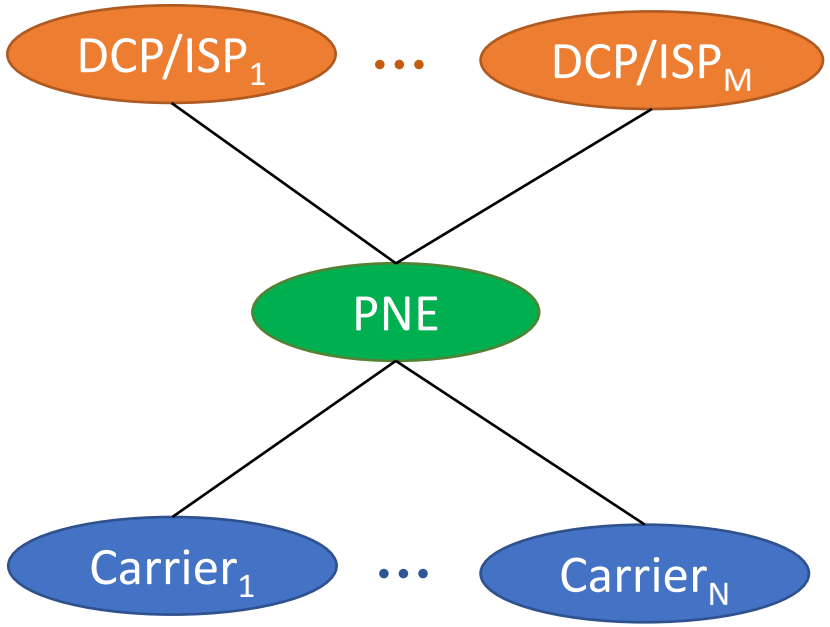

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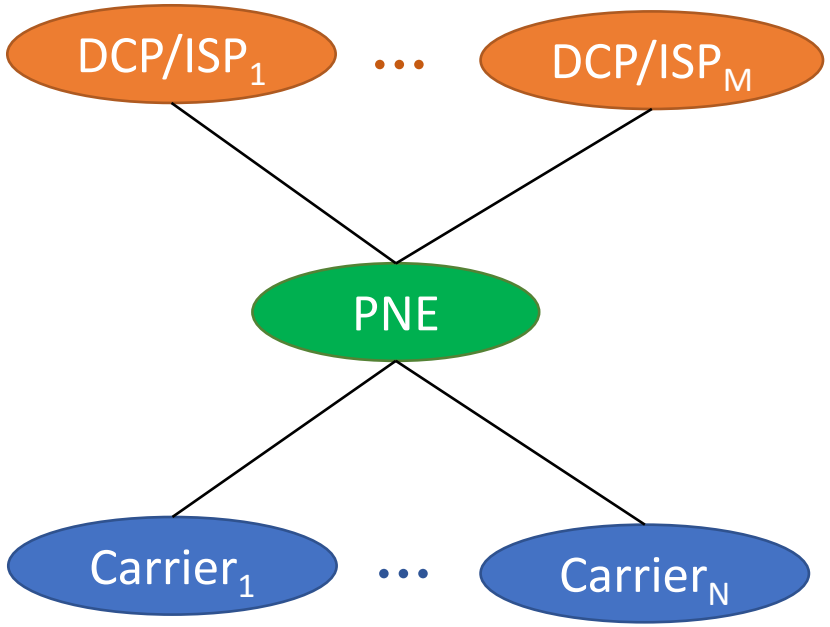

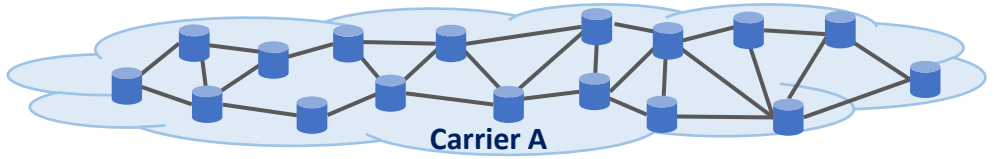

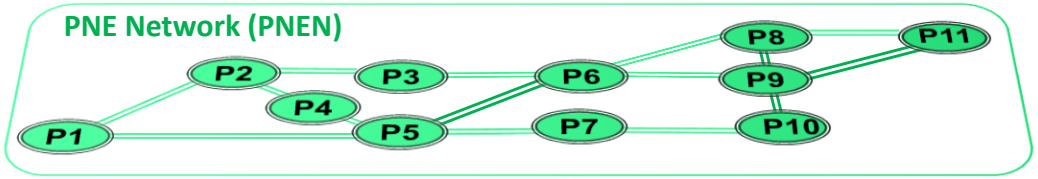

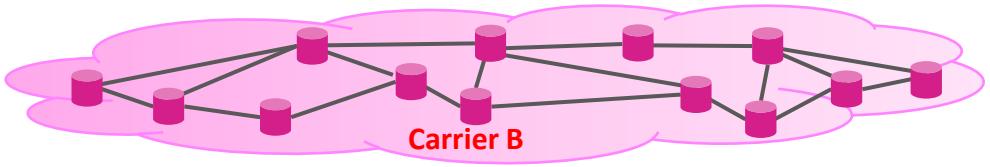

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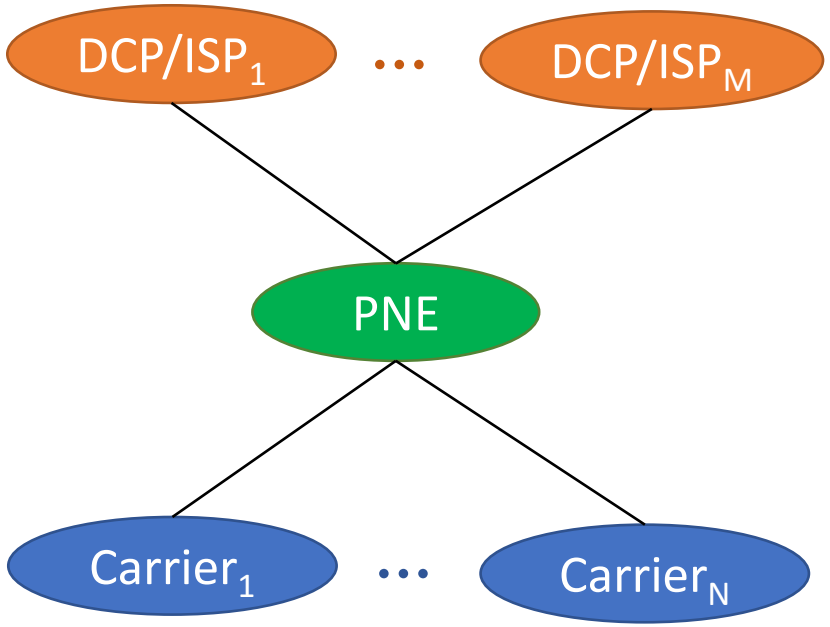
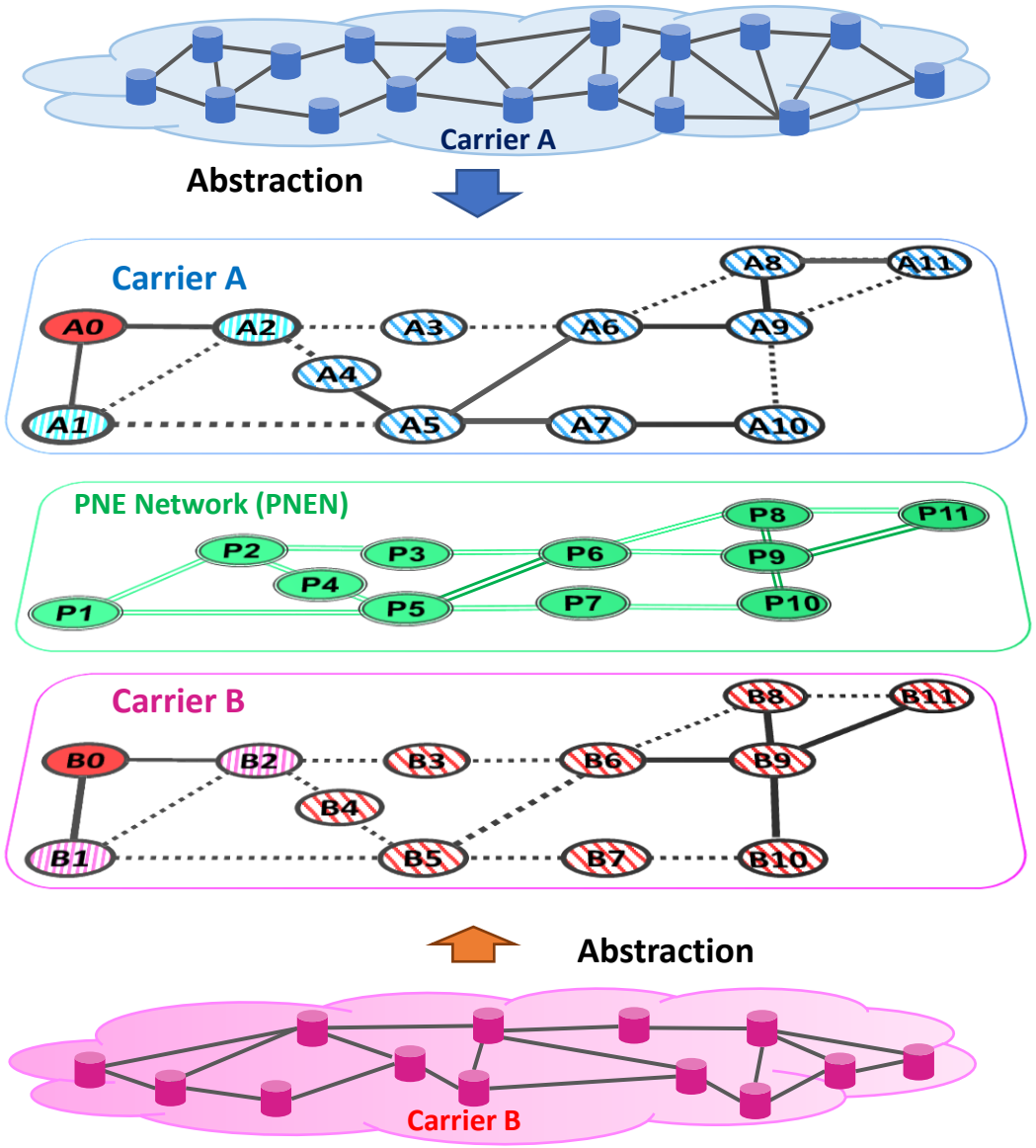
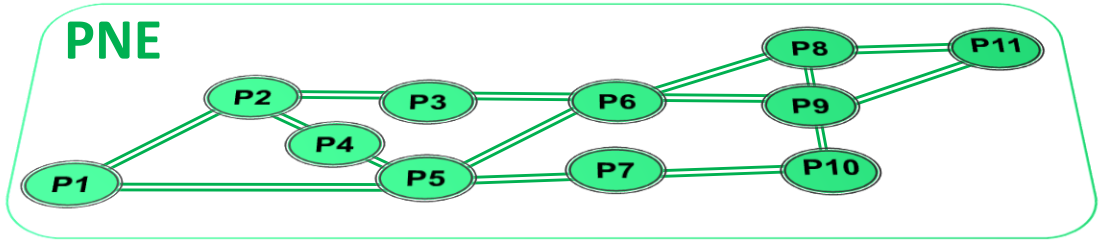
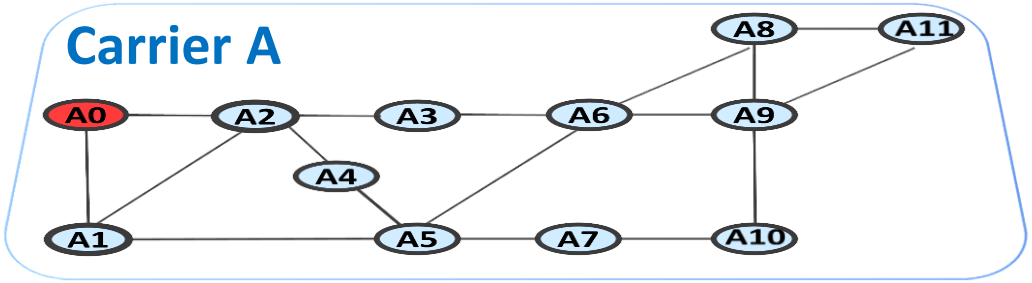


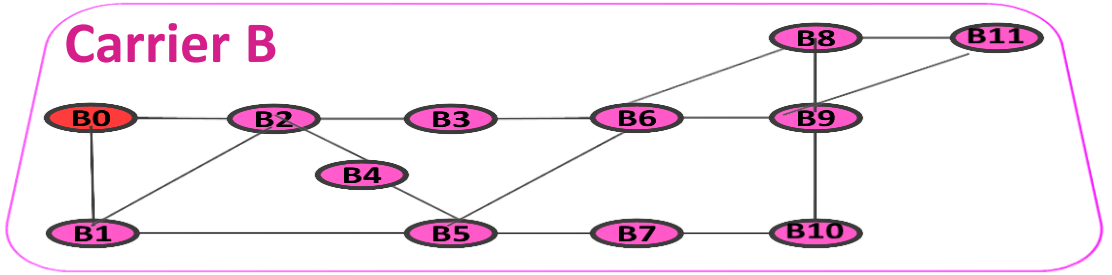


The interconnection between different entities in the ecosystem

Preemptive and Early Failure Detection and Management

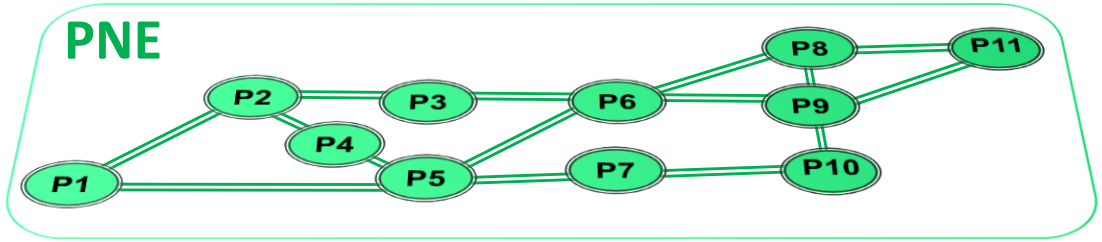


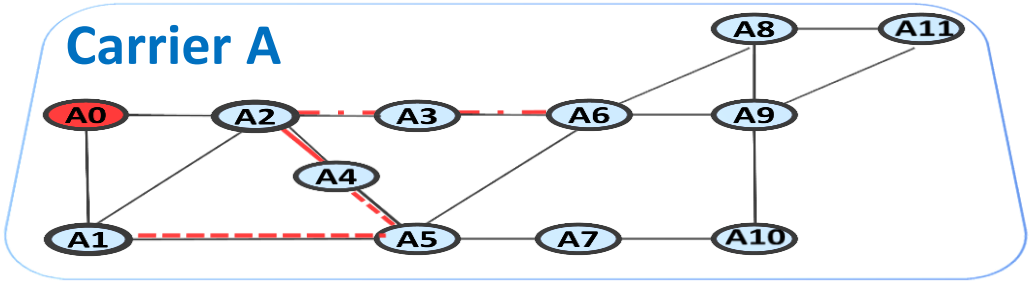


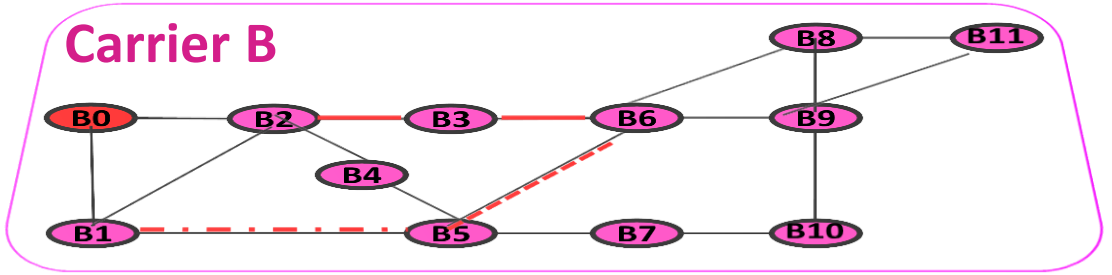


The interconnection between different entities in the ecosystem

Preemptive and Early Failure Detection and Management







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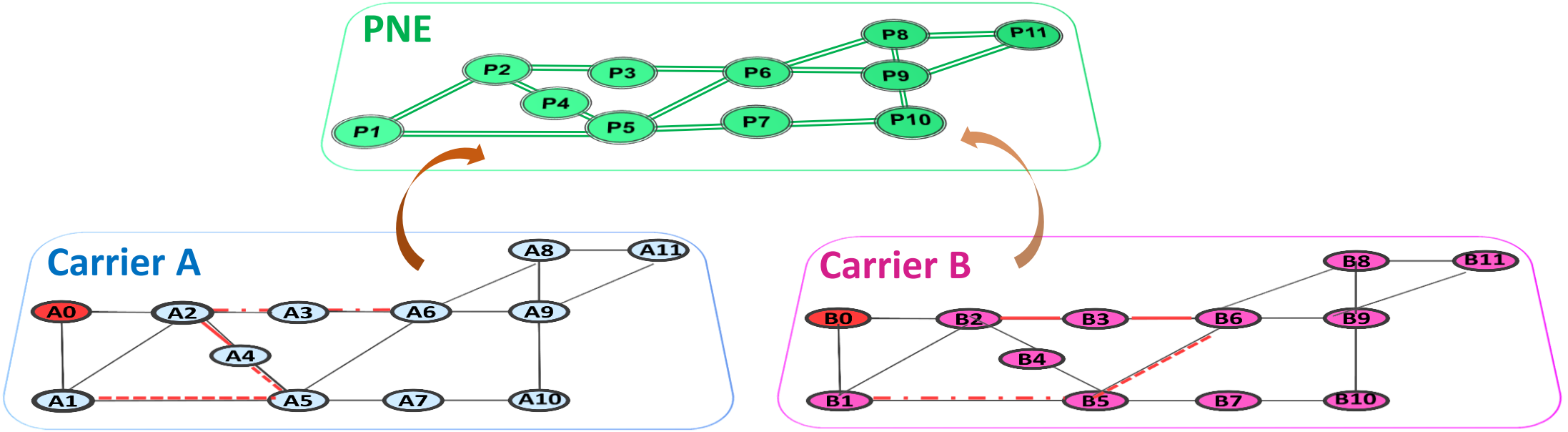
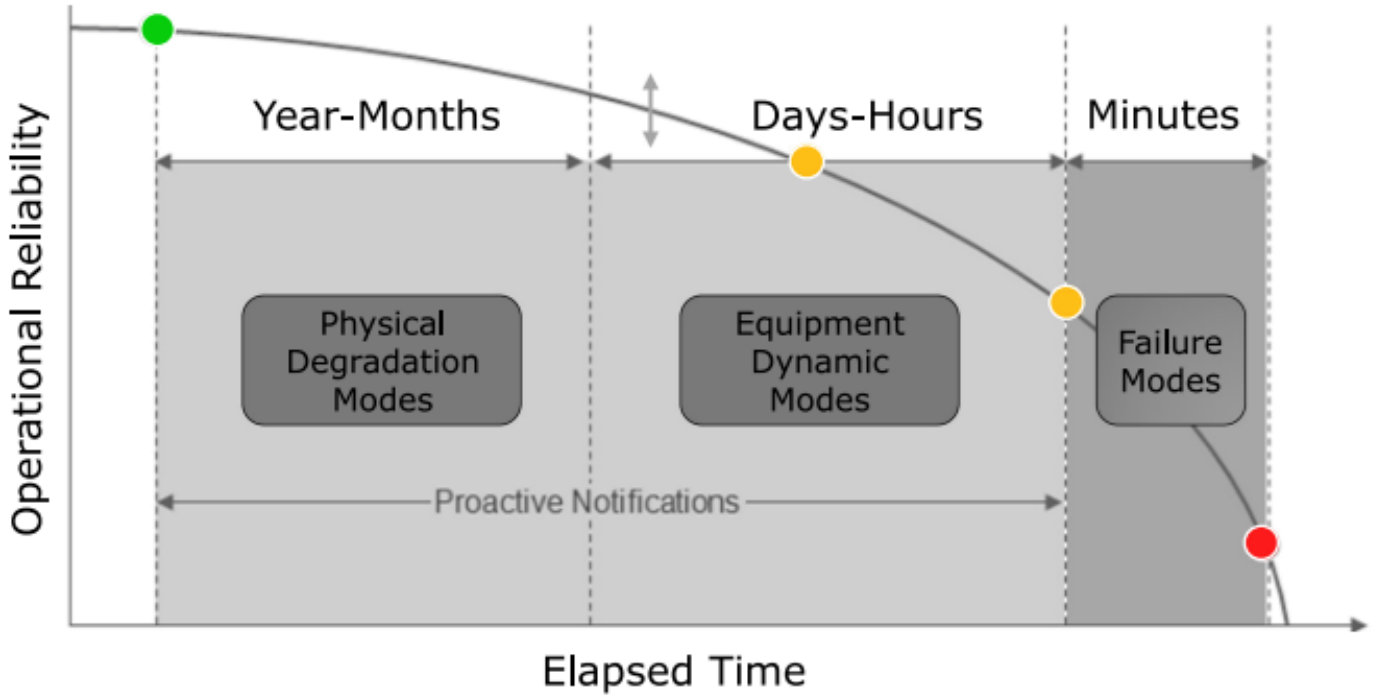
Preemptive and Early Failure Detection and Management



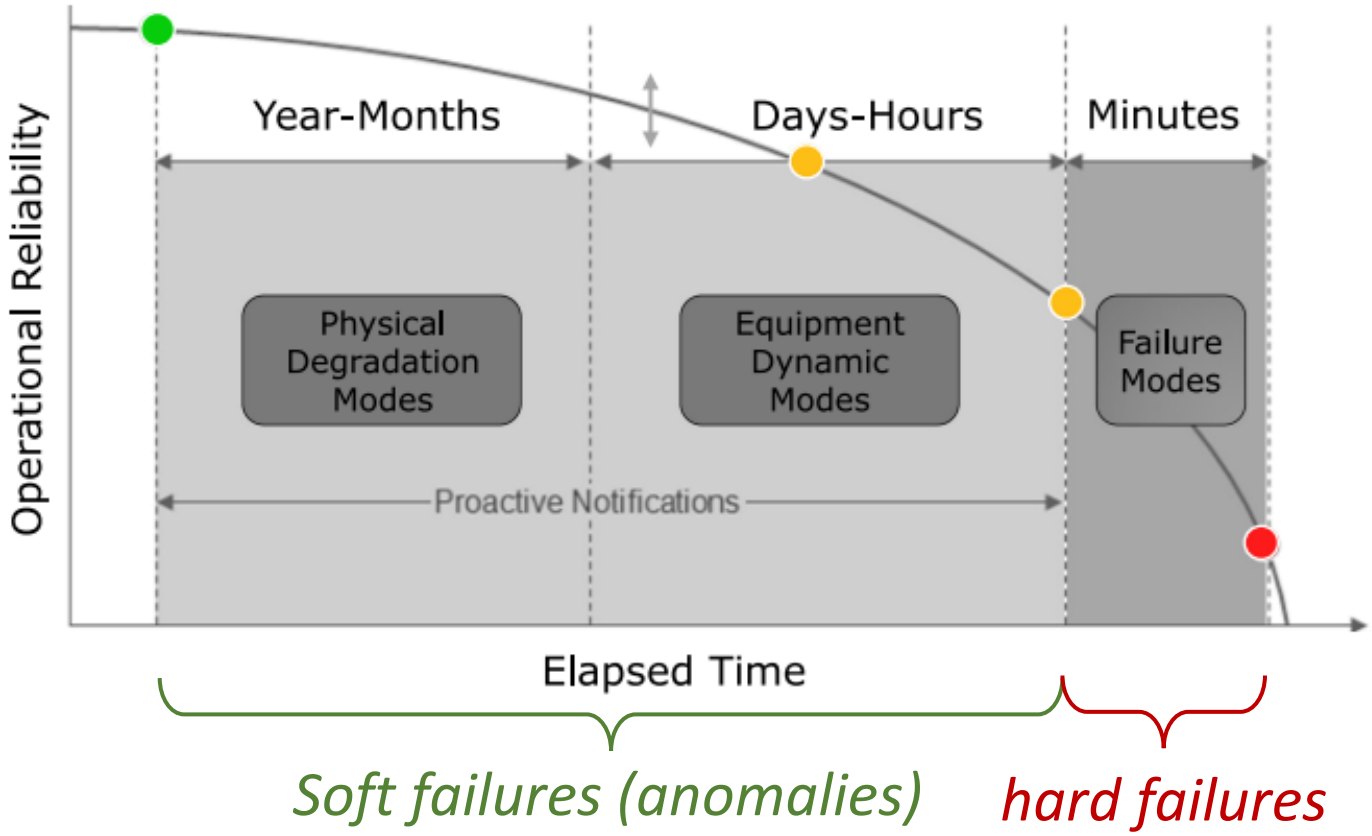
Degradation/disconnection at the physical layer needs ***preemptive*** *and* ***early*** *detection and management*

Preemptive and Early Failure Detection and Management



D. Rafique, T. Szyrkowiec, H. Grießer, A. Autenrieth and J. -P. Elbers, "Cognitive Assurance Architecture for Optical Network Fault Management," in *Journal of Lightwave Technology*, vol. 36, no. 7, pp. 1443-1450, 1 April1, 2018.

Preemptive and Early Failure Detection and Management



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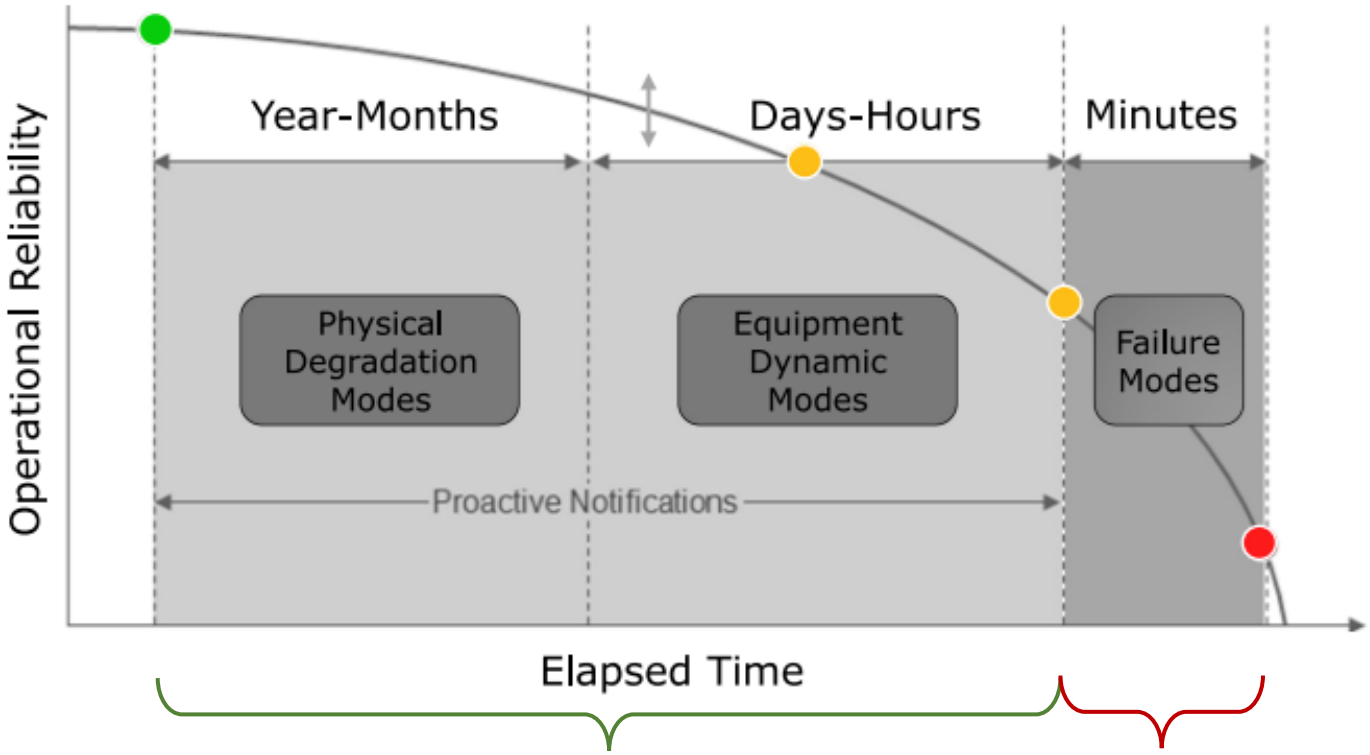
Preemptive and Early Failure Detection and Management

PREEMPTIVE



Gradual degradation of the network operations

Soft failures (anomalies)

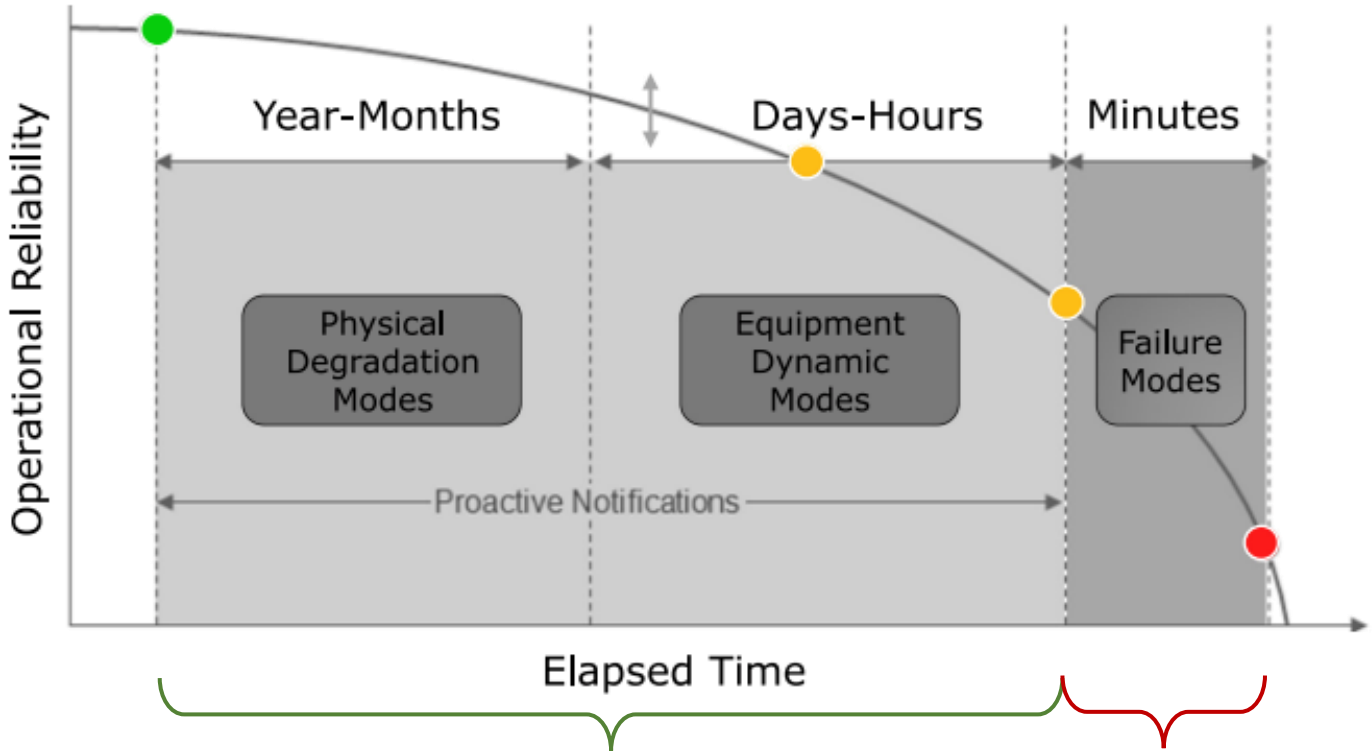
hard failures

D. Rafique, T. Szyrkowiec, H. Grießer, A. Autenrieth and J. -P. Elbers, "Cognitive Assurance Architecture for Optical Network Fault Management," in *Journal of Lightwave Technology*, vol. 36, no. 7, pp. 1443-1450, 1 April1, 2018.

Preemptive and Early Failure Detection and Management

PREEMPTIVE

EARLY



Gradual degradation of the network operations

Immediate service disruptions

Soft failures (anomalies)

hard failures

D. Rafique, T. Szyrkowiec, H. Grießer, A. Autenrieth and J. -P. Elbers, "Cognitive Assurance Architecture for Optical Network Fault Management," in *Journal of Lightwave Technology*, vol. 36, no. 7, pp. 1443-1450, 1 April1, 2018.

Behavioral Modeling and ML Techniques for Threat Detection

Cisco Security Analytics (2020), “A deep-dive into the unique behavioral modeling and machine learning techniques for advanced threat detection and response [White Paper],” https://www.cisco.com/c/en/us/products/collateral/security/stealthwatch/white-paper-c11-740605.pdf.

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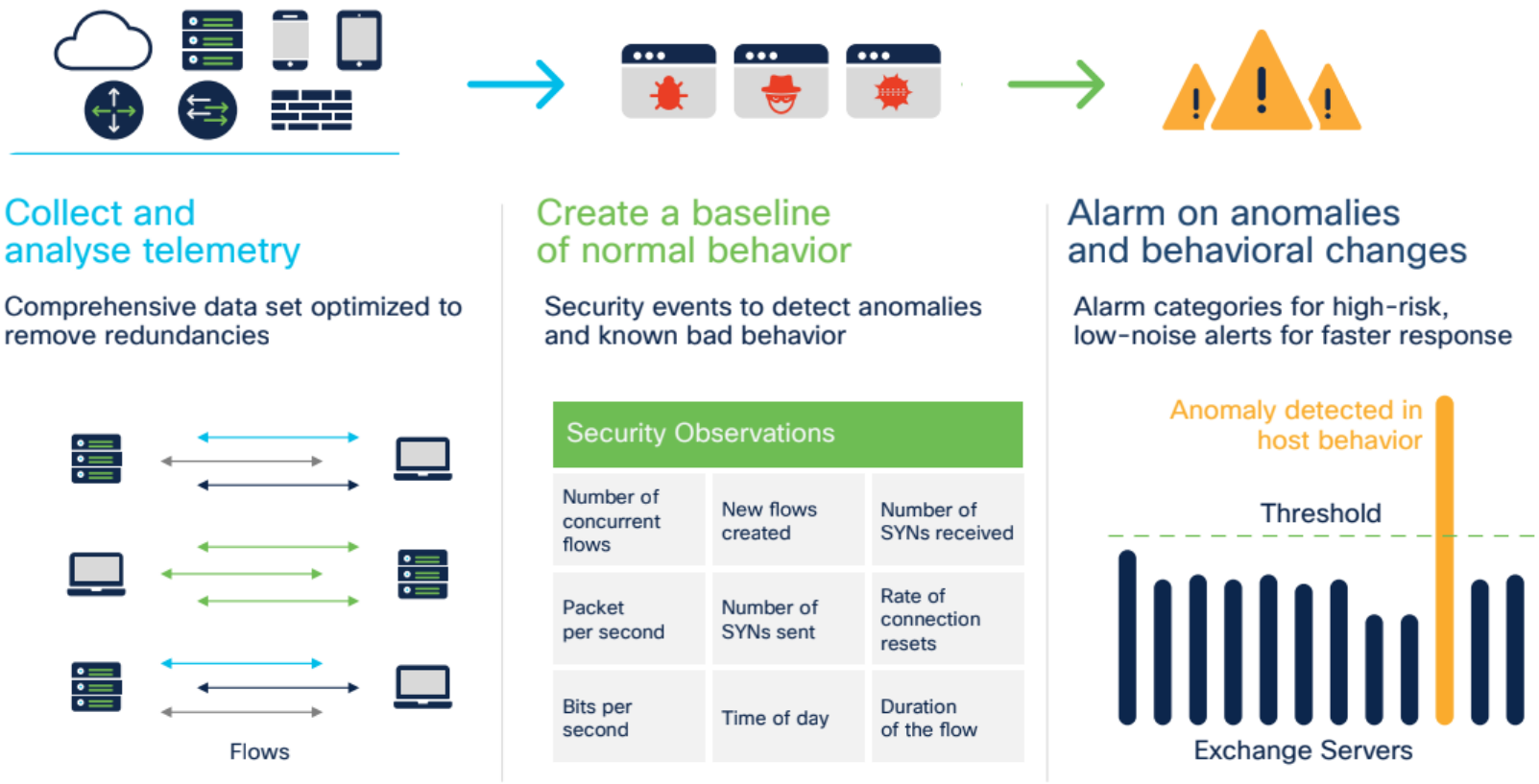

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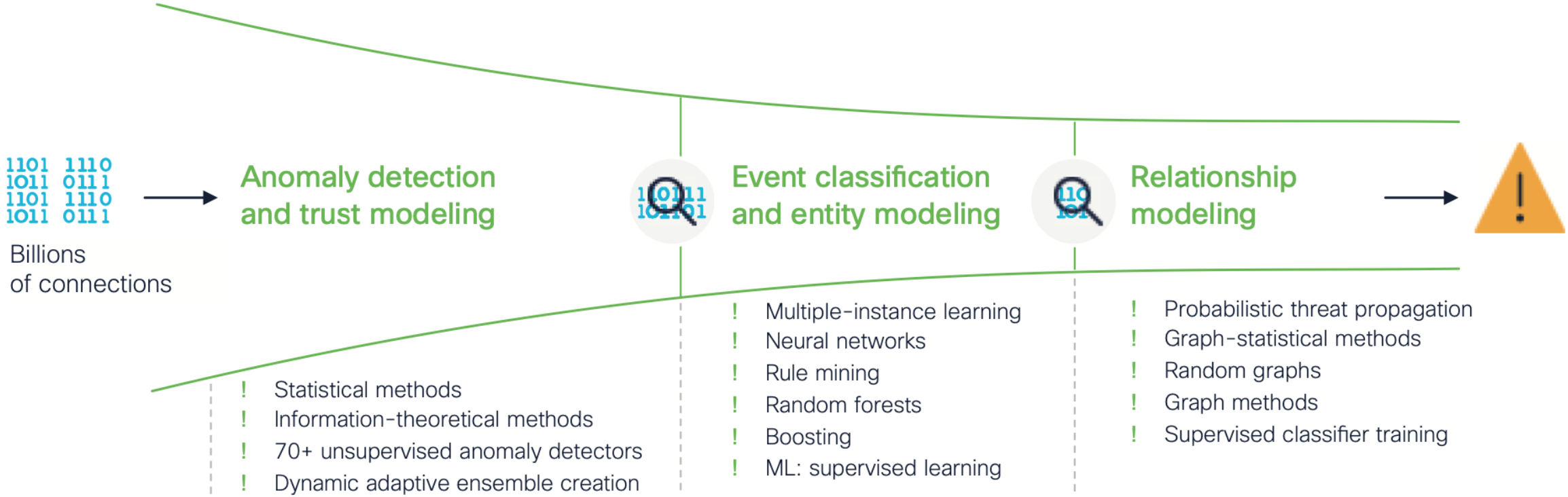

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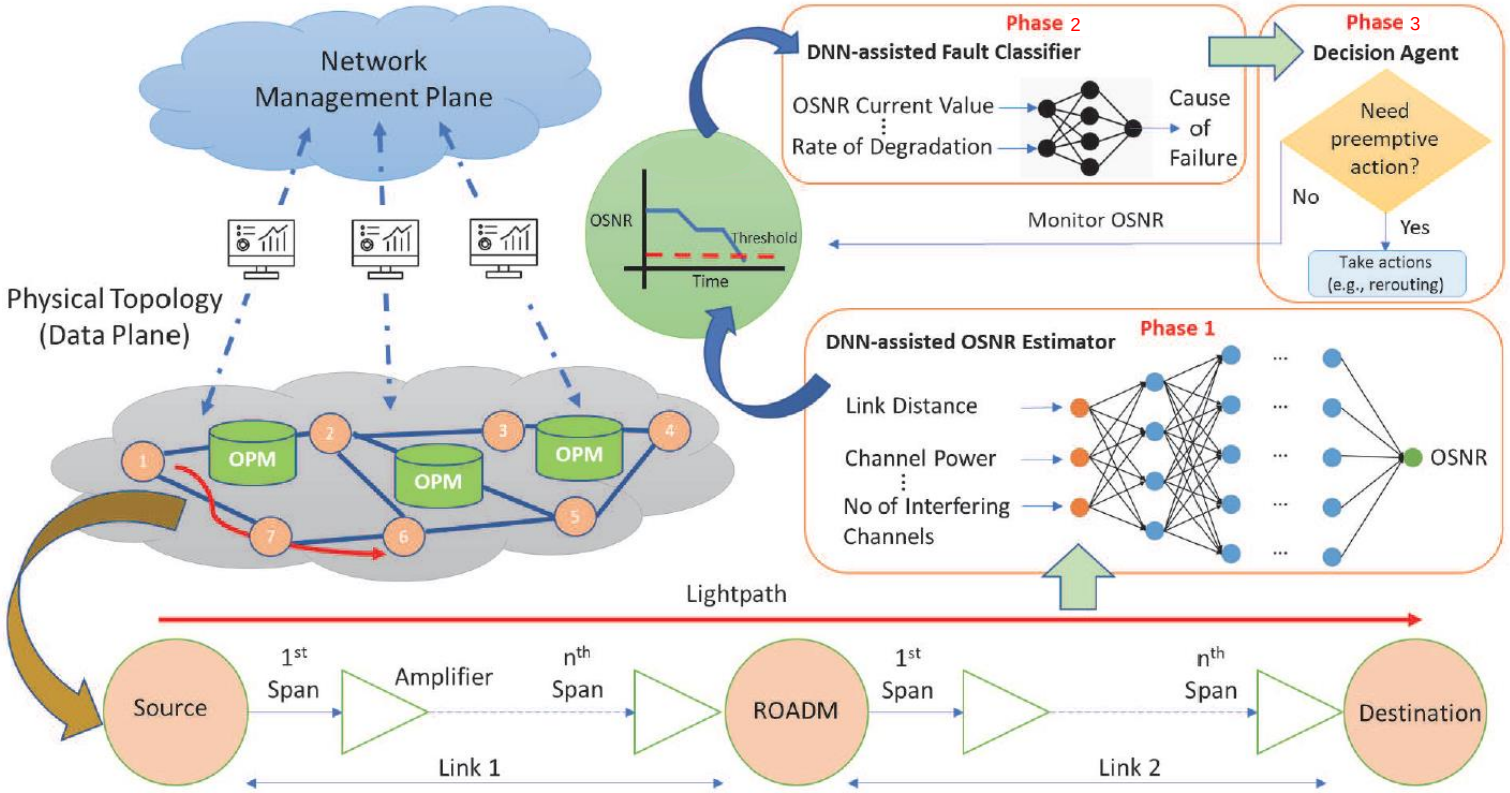
General Overview of The Proposed Framework in Single Entity

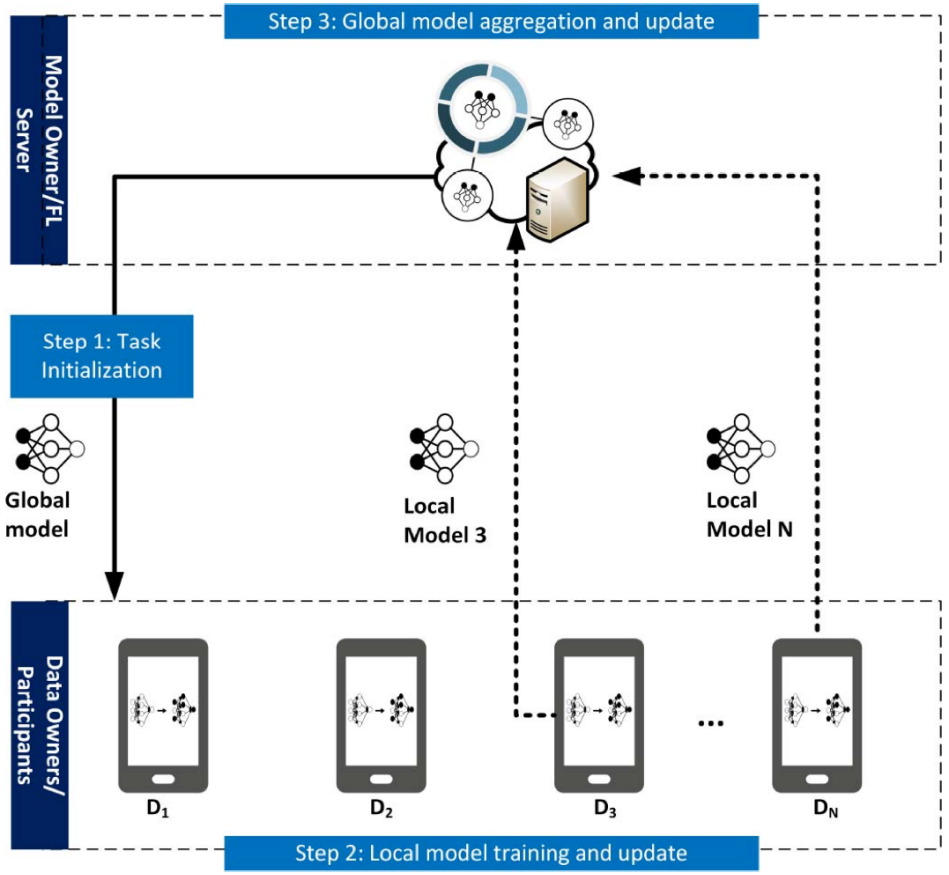


Preemptive failure detection and management (PFDM) framework

Highly Efficient Estimations and Classifications using Federated Learning

W. Y. B. Lim et al., "Federated Learning in Mobile Edge Networks: A Comprehensive Survey," in *IEEE Communications Surveys & Tutorials*, vol. 22, no. 3, pp. 2031-2063, thirdquarter 2020.

Highly Efficient Estimations and Classifications using Federated Learning



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The interconnection between different entities in the ecosystem

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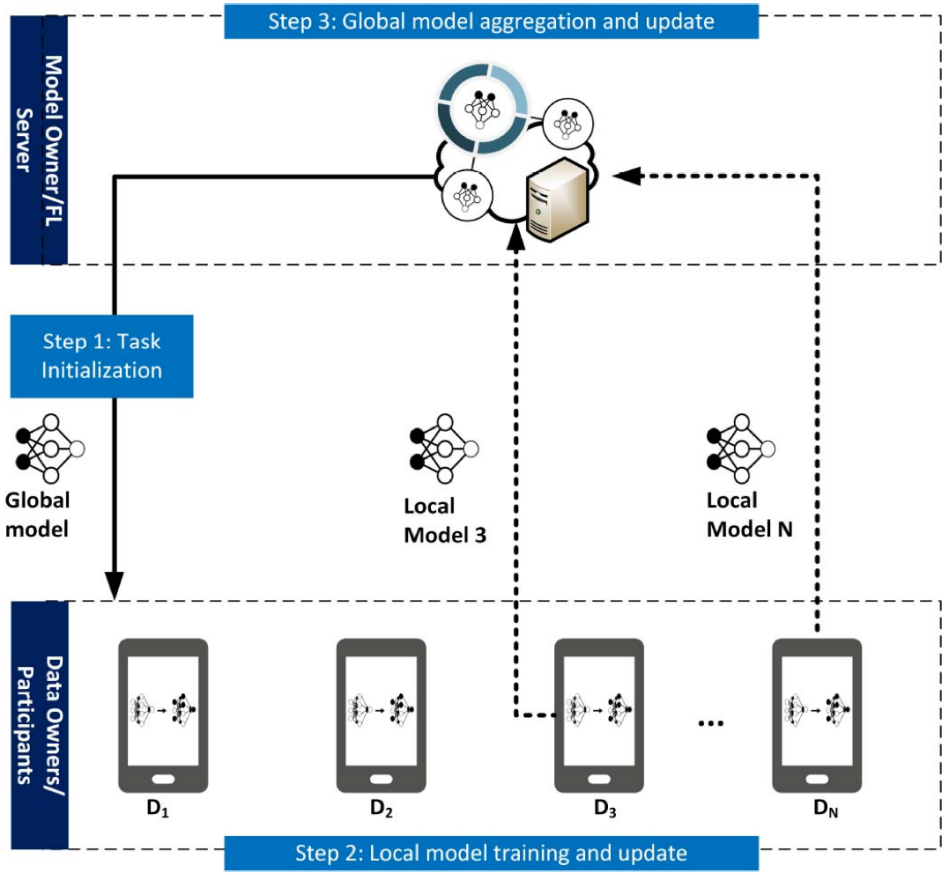
Highly Efficient Estimations and Classifications using Federated Learning

PNE

Carriers



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The interconnection between different entities in the ecosystem

From Local to Federated

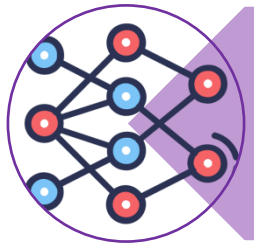
The interconnection between different entities in the ecosystem

From Local to Federated

Federated Survivability Framework in Multi-Domain Optical Networks

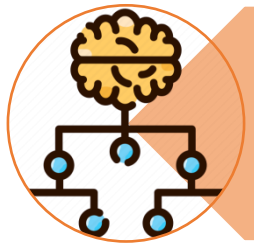
The interconnection between different entities in the ecosystem

Phases of The Proposed Framework



Phase I

- Abstraction and OSNR Estimation



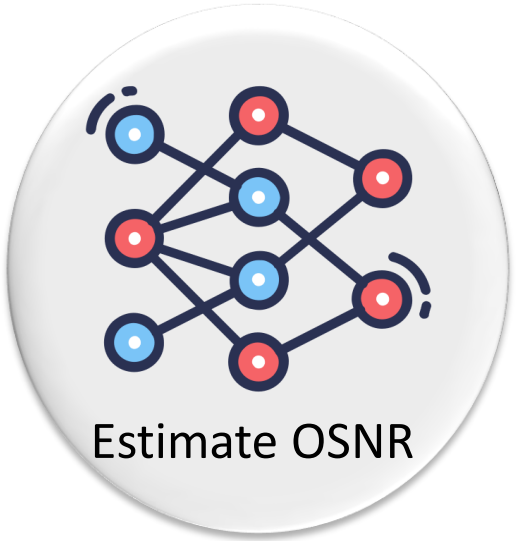
Phase II

- Failure Classification and Cost Evaluation

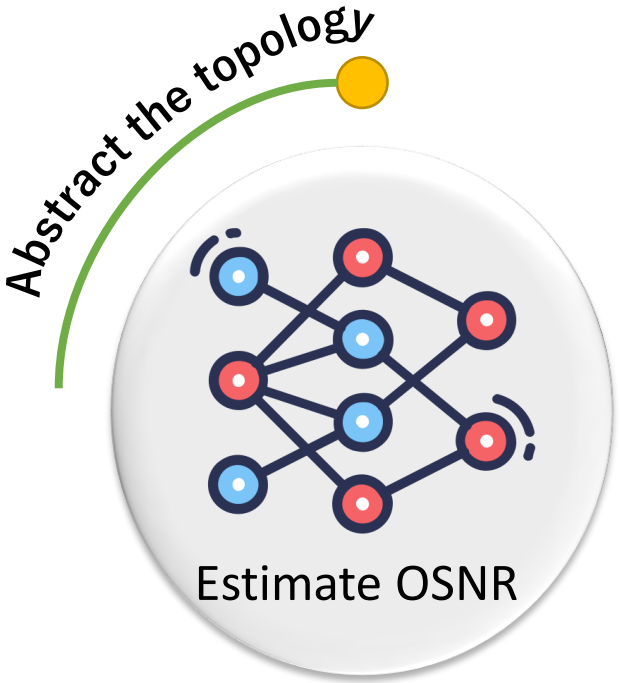
Phase III

- Negotiation and Post-Failure Action

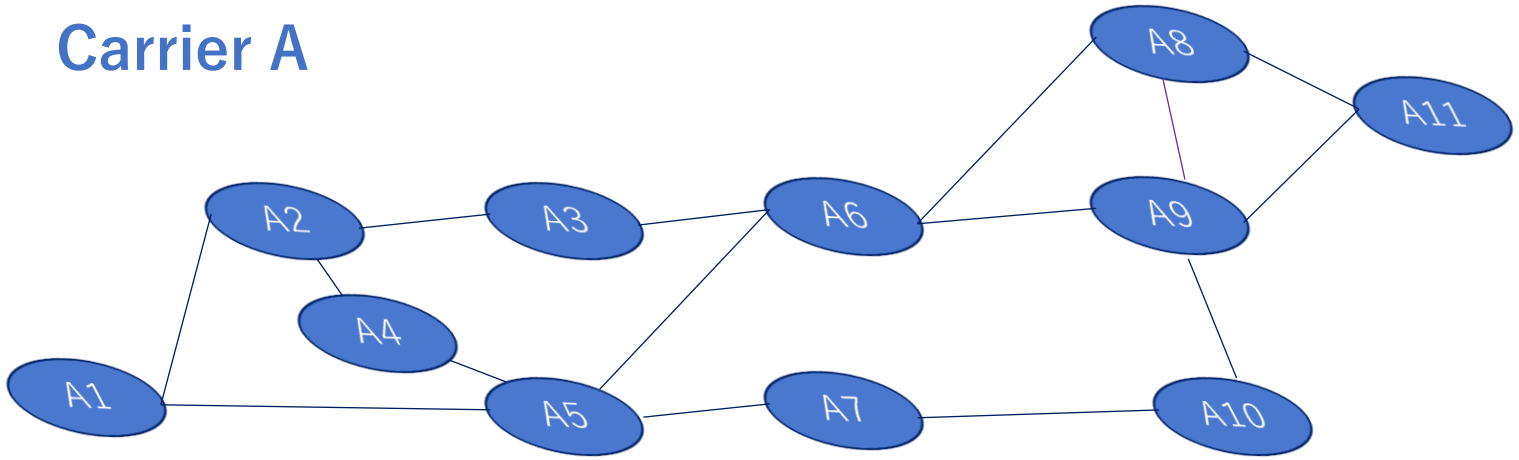
Flow of The Proposed Framework



Flow of The Proposed Framework

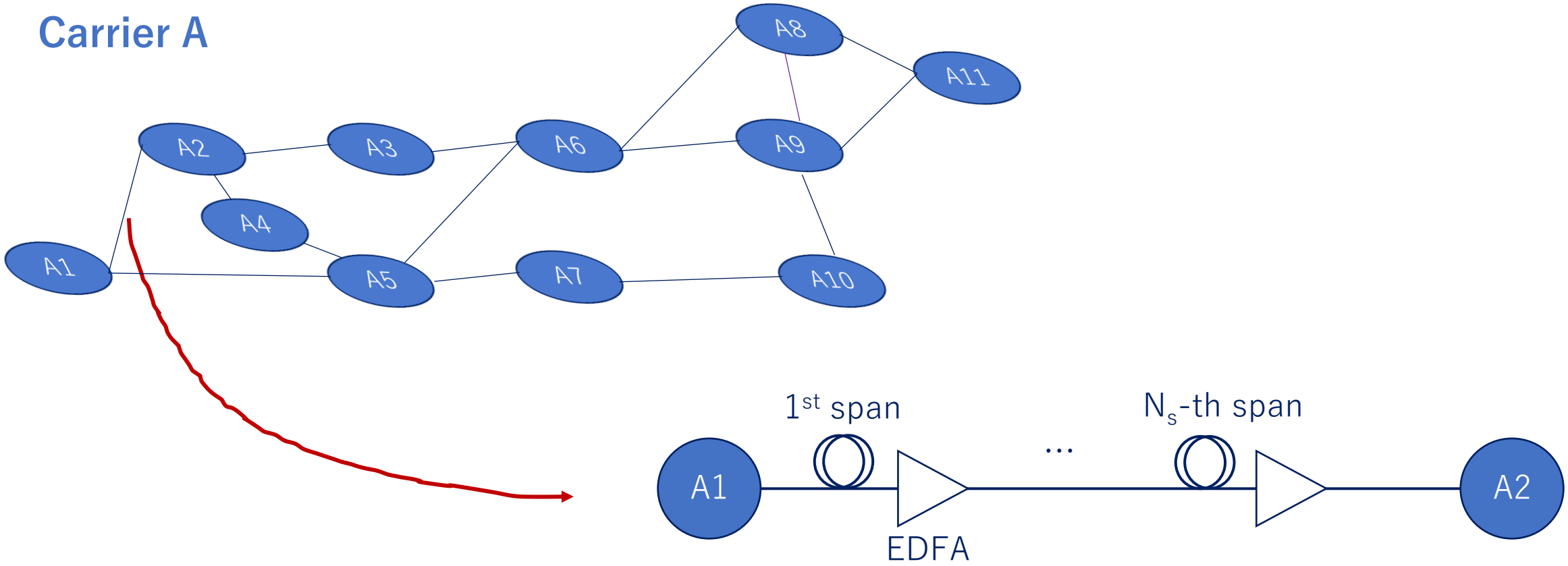


Phase I: Abstraction and OSNR Estimation



The interconnection between different entities in the ecosystem

Phase I: Abstraction and OSNR Estimation



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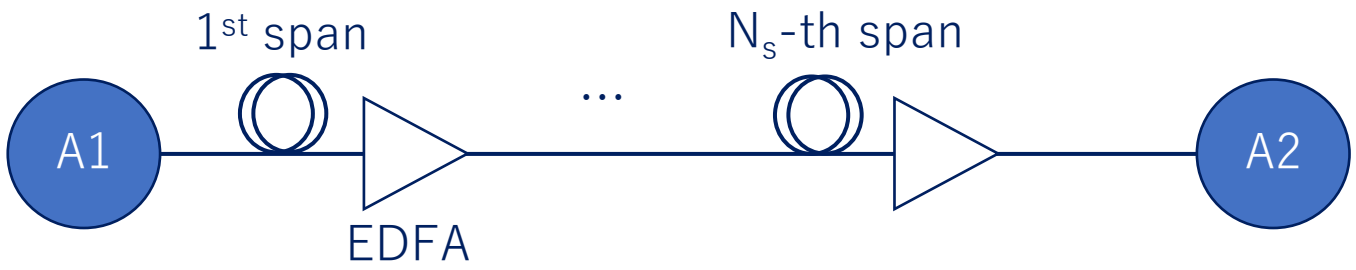

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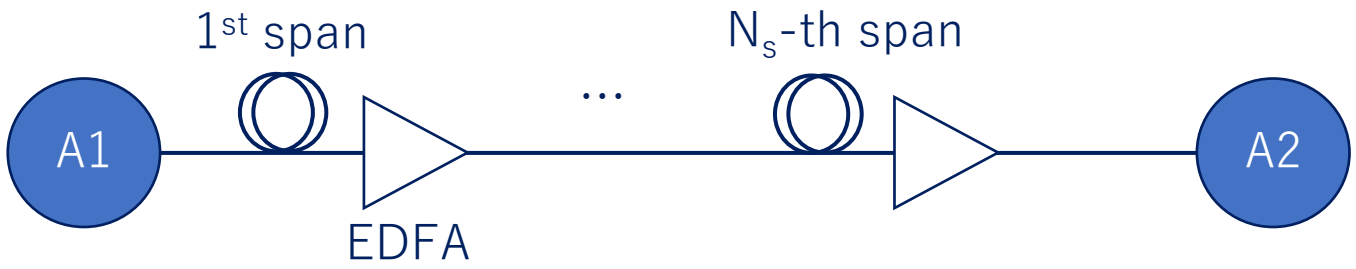
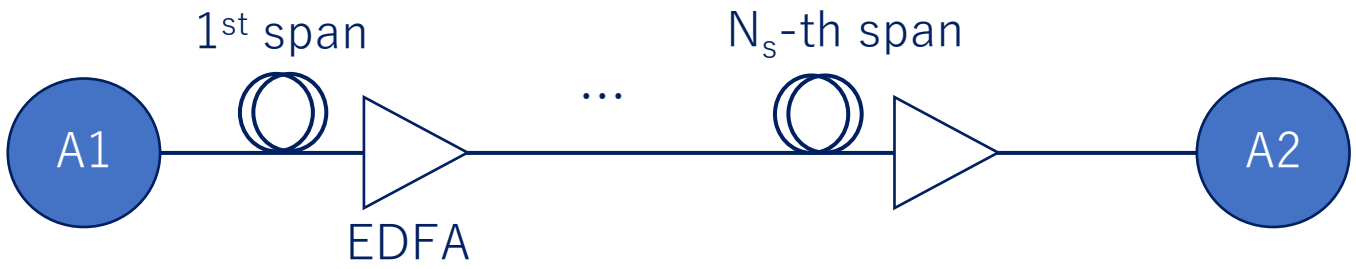


$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

Phase I: Abstraction and OSNR Estimation



$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

frequency

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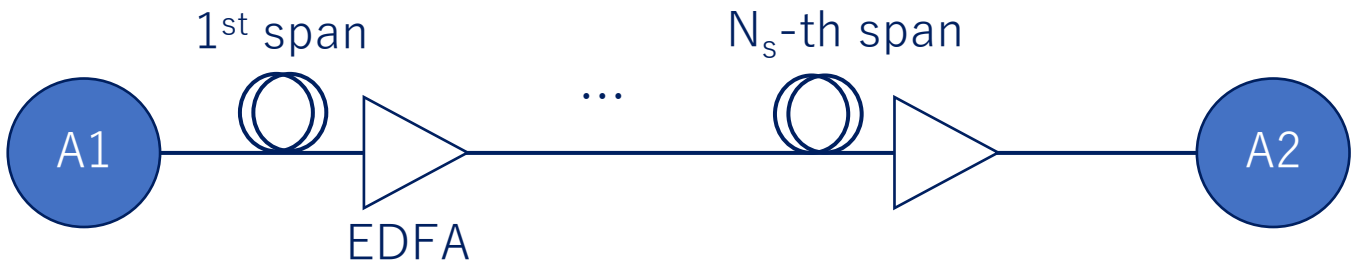
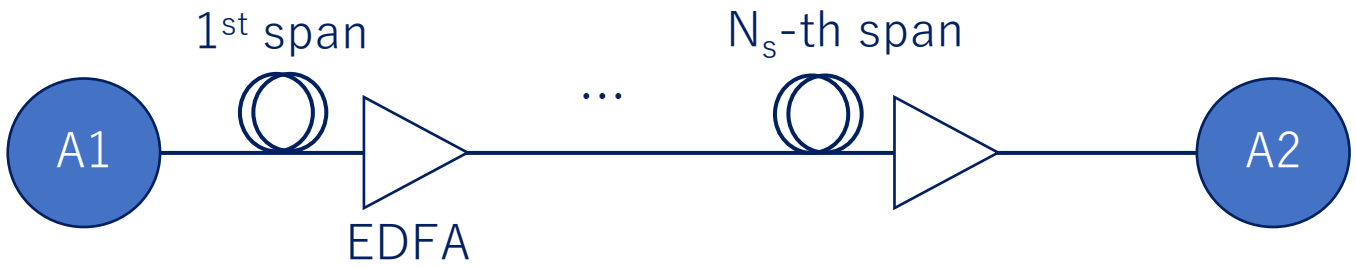


ASE noise

$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

frequency

Phase I: Abstraction and OSNR Estimation

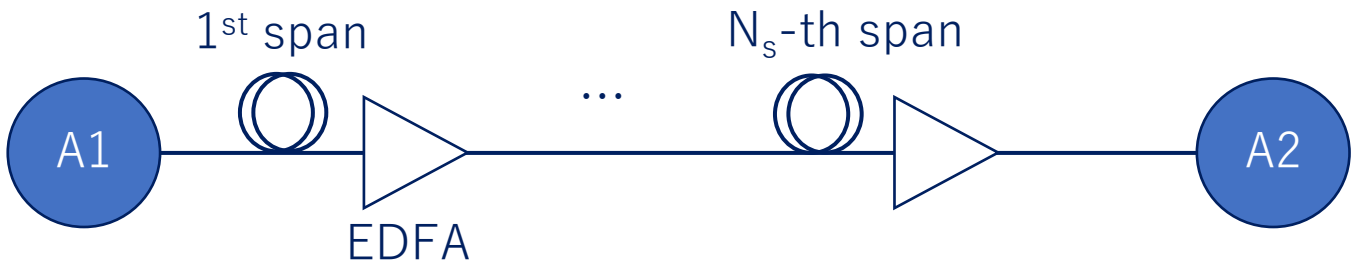


ASE noise Cumulative NLI

$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

frequency

Phase I: Abstraction and OSNR Estimation



$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

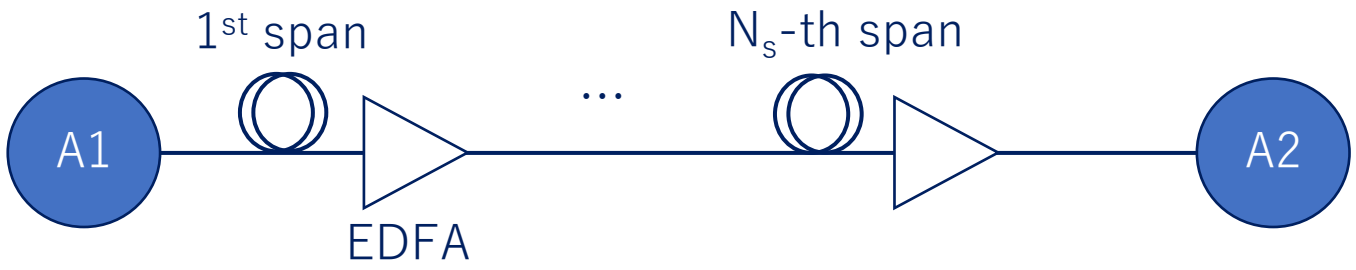
ASE noise

Cumulative NLI

frequency

Channel power

Phase I: Abstraction and OSNR Estimation



$$OSNR_l^{-1}(f) = \frac{P_{ASE}^l(f) + P_{NLI}^l(f)}{P_{ch}}$$

ASE noise

Cumulative NLI

frequency

Channel power

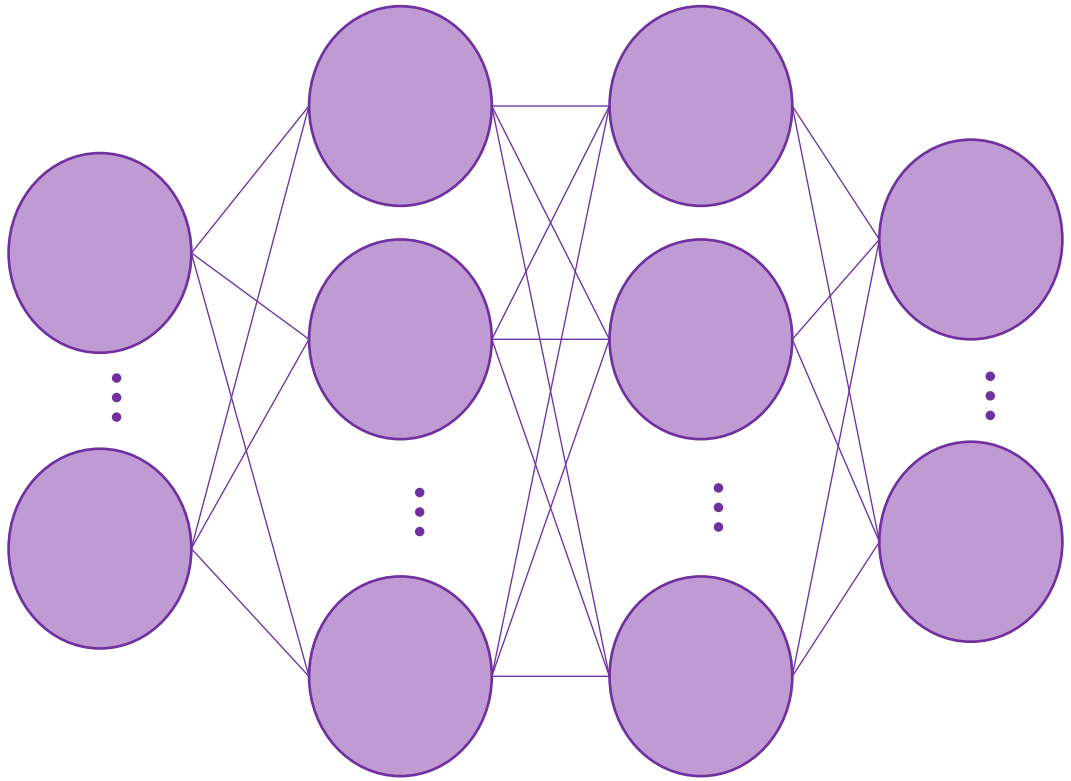
General Features
Channel Power
Modulation Level
Link Length
Frequency

ASE Features
# of span
Span length
Spontaneous emission factor
In-line EDFA gain
Reference Bandwidth
Planck constant

NLI Features
# of active channels
Power of interfering channels
NL coefficient
Phase mismatch
Loss

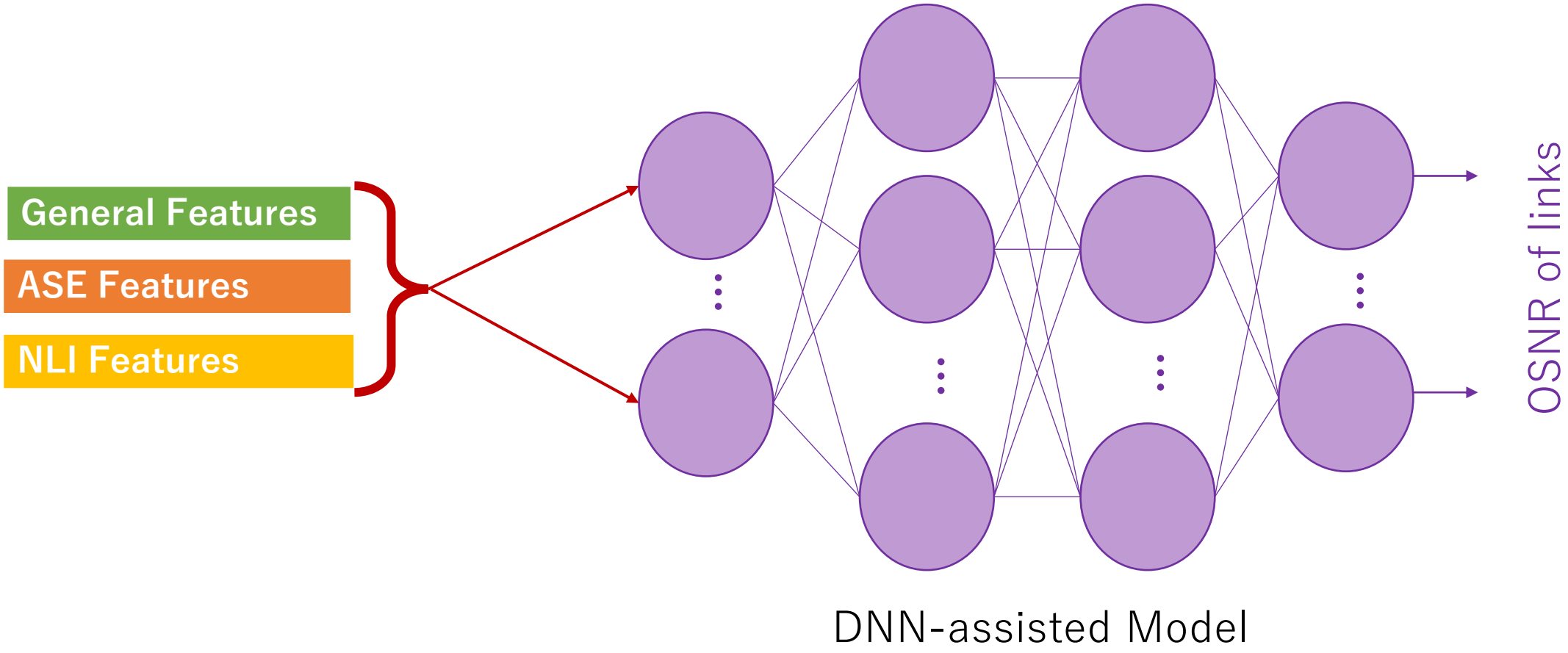
Phase I: Abstraction and OSNR Estimation

Phase I: Abstraction and OSNR Estimation



DNN-assisted Model

Phase I: Abstraction and OSNR Estimation



Phase I: Abstraction and OSNR Estimation

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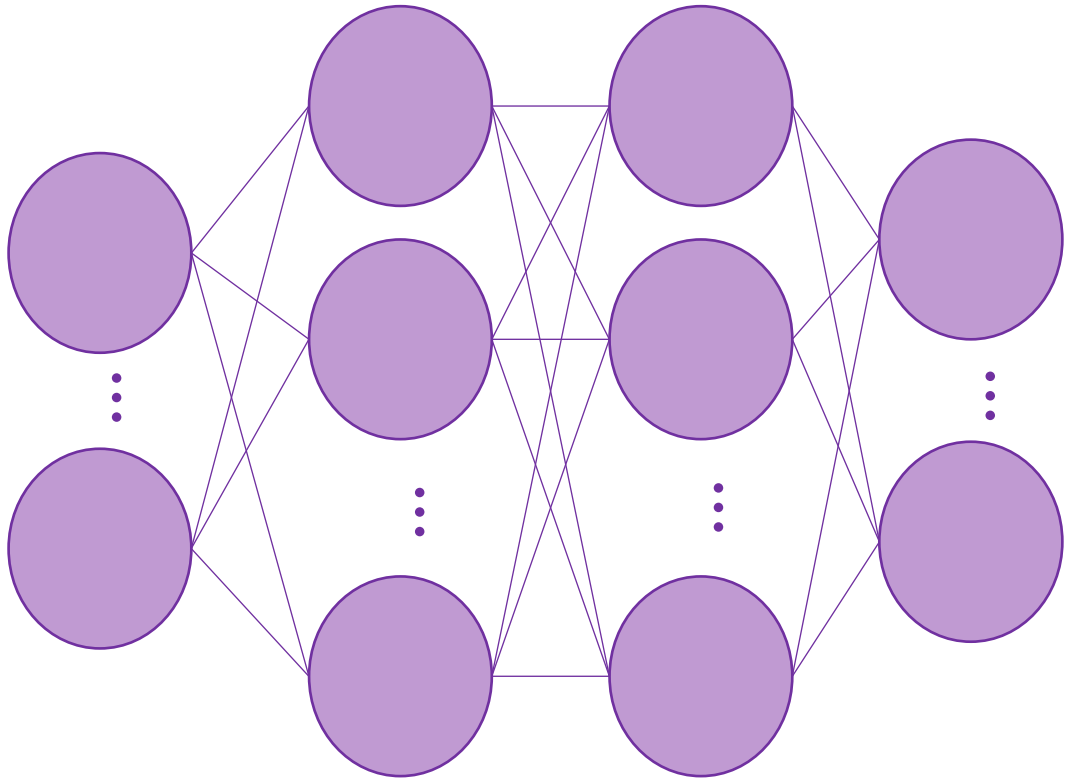

DNN-assisted Model

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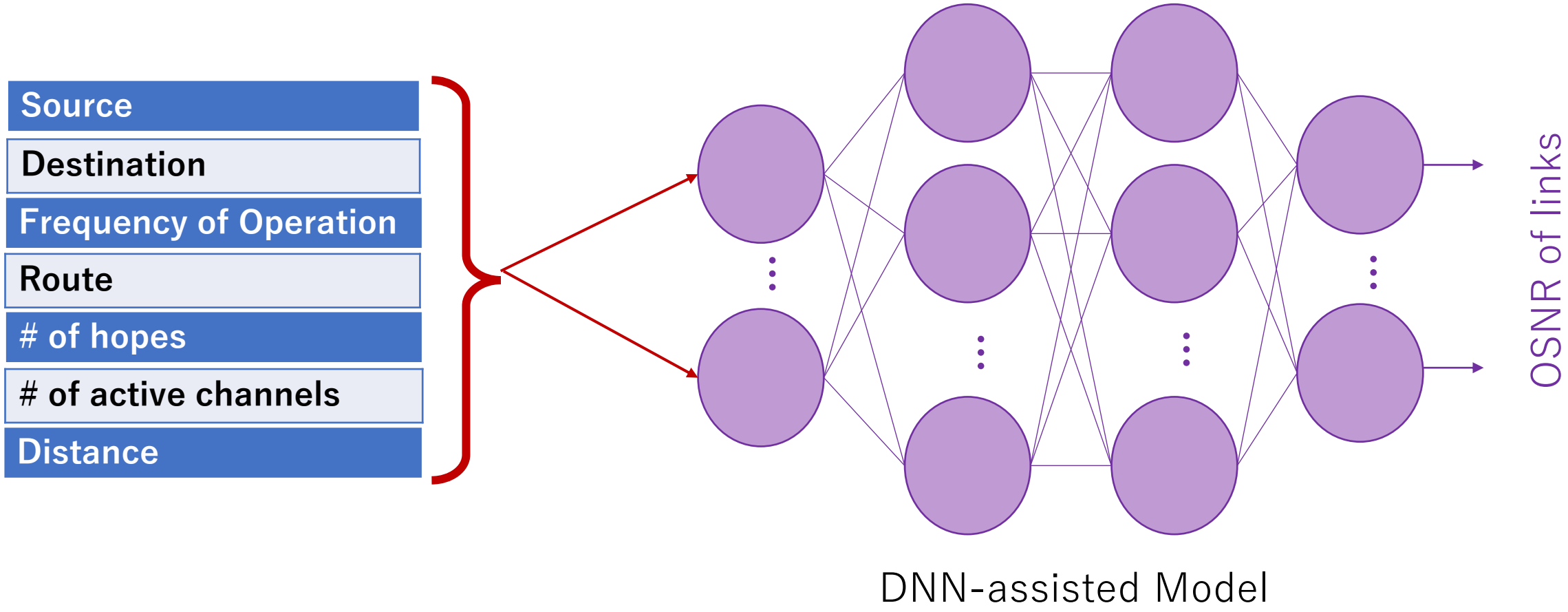
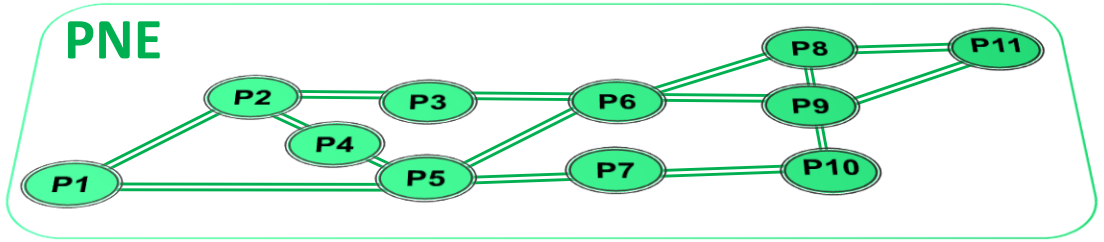
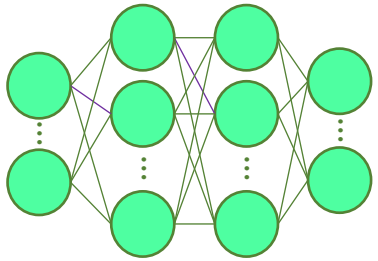
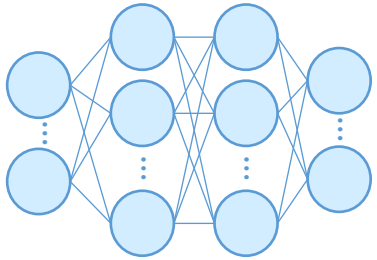
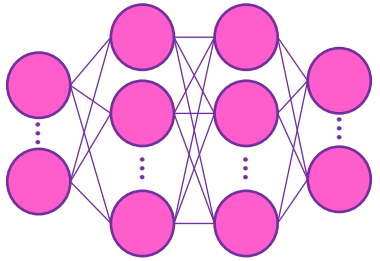


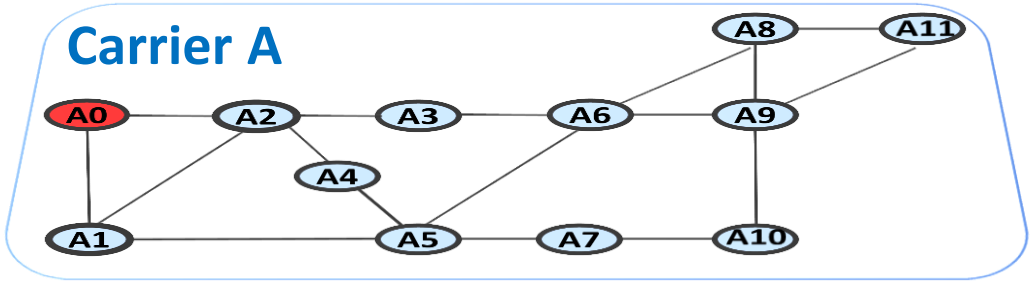
Phase I: Federated Learning-based OSNR Estimation Model

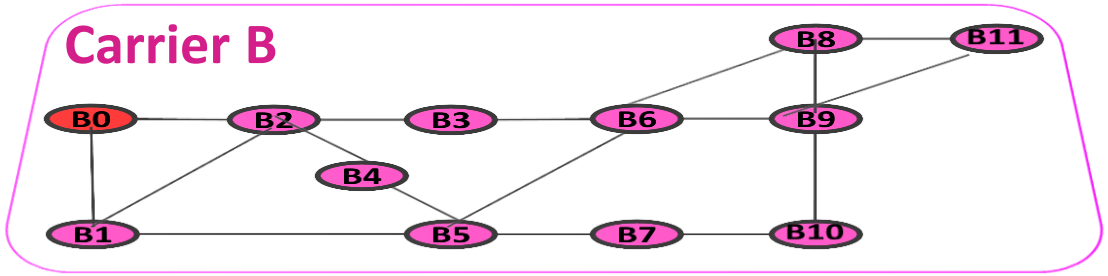












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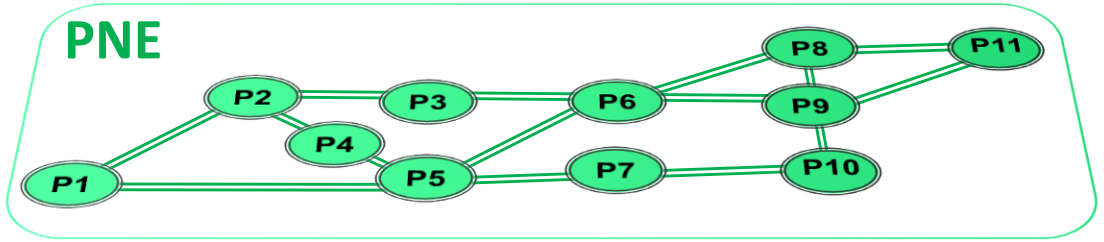
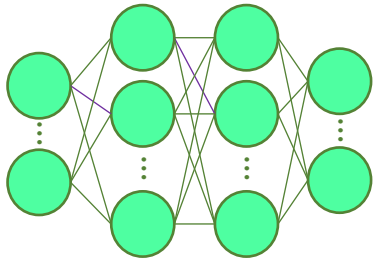
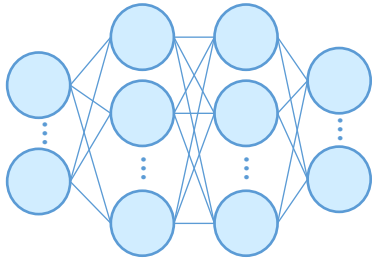
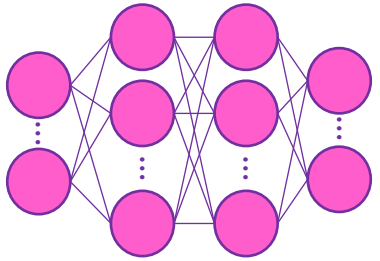
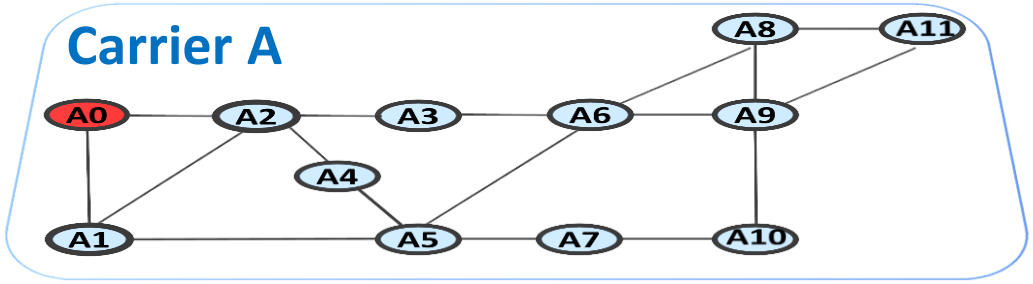


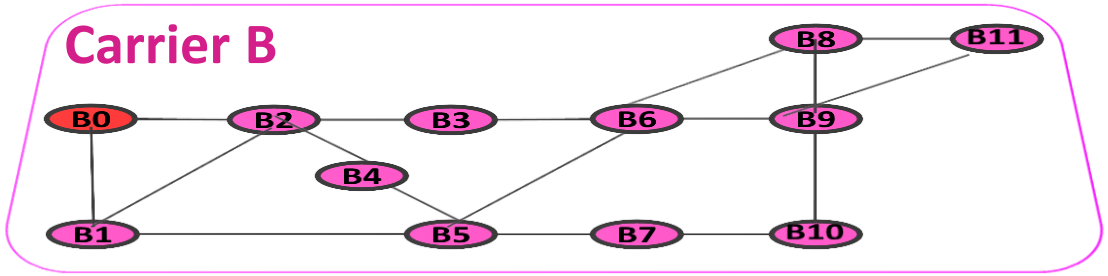


$$\boldsymbol{w} = [w_1, w_2, \ldots, w_n]$$









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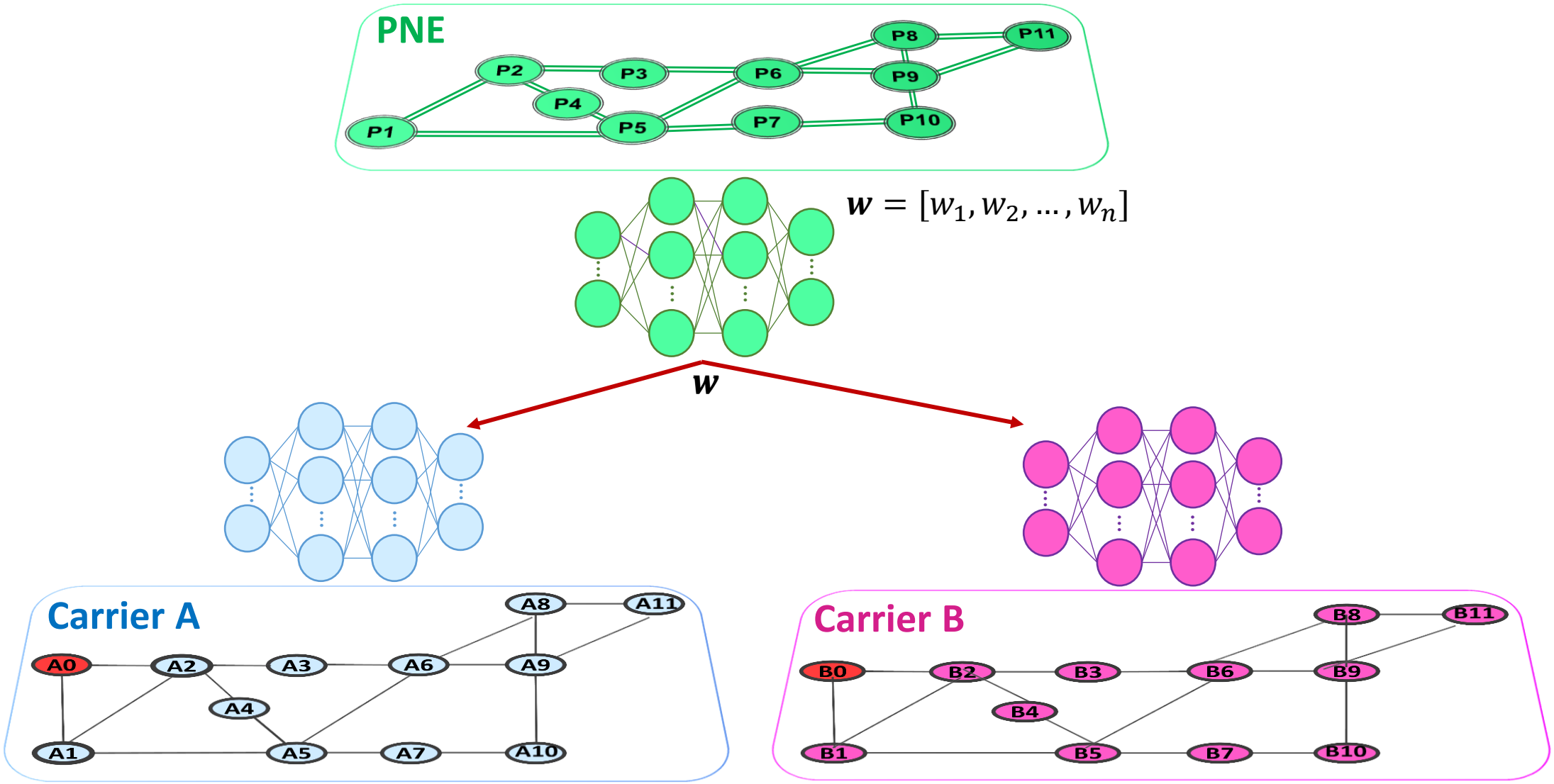

The interconnection between different entities in the ecosystem

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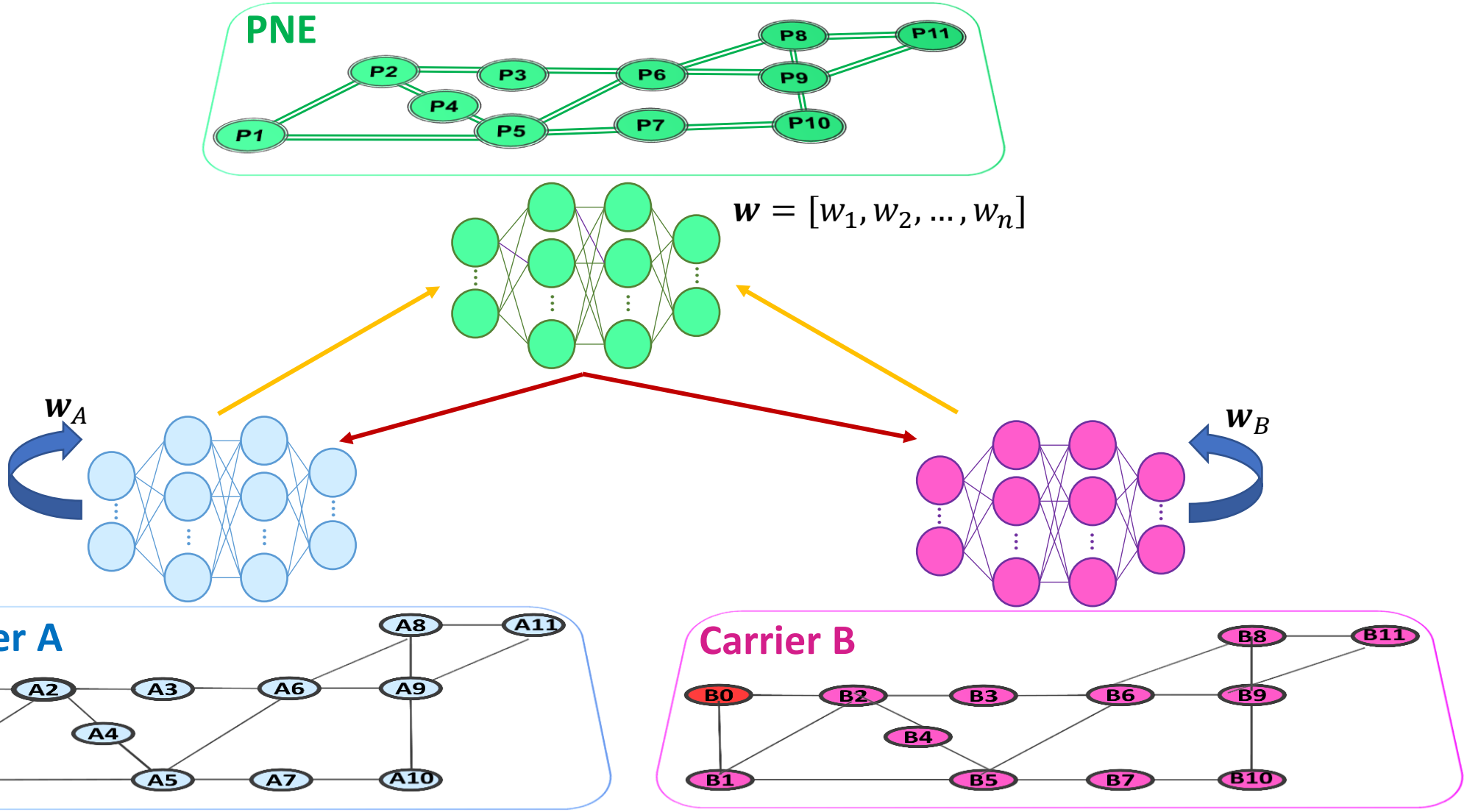

The interconnection between different entities in the ecosystem

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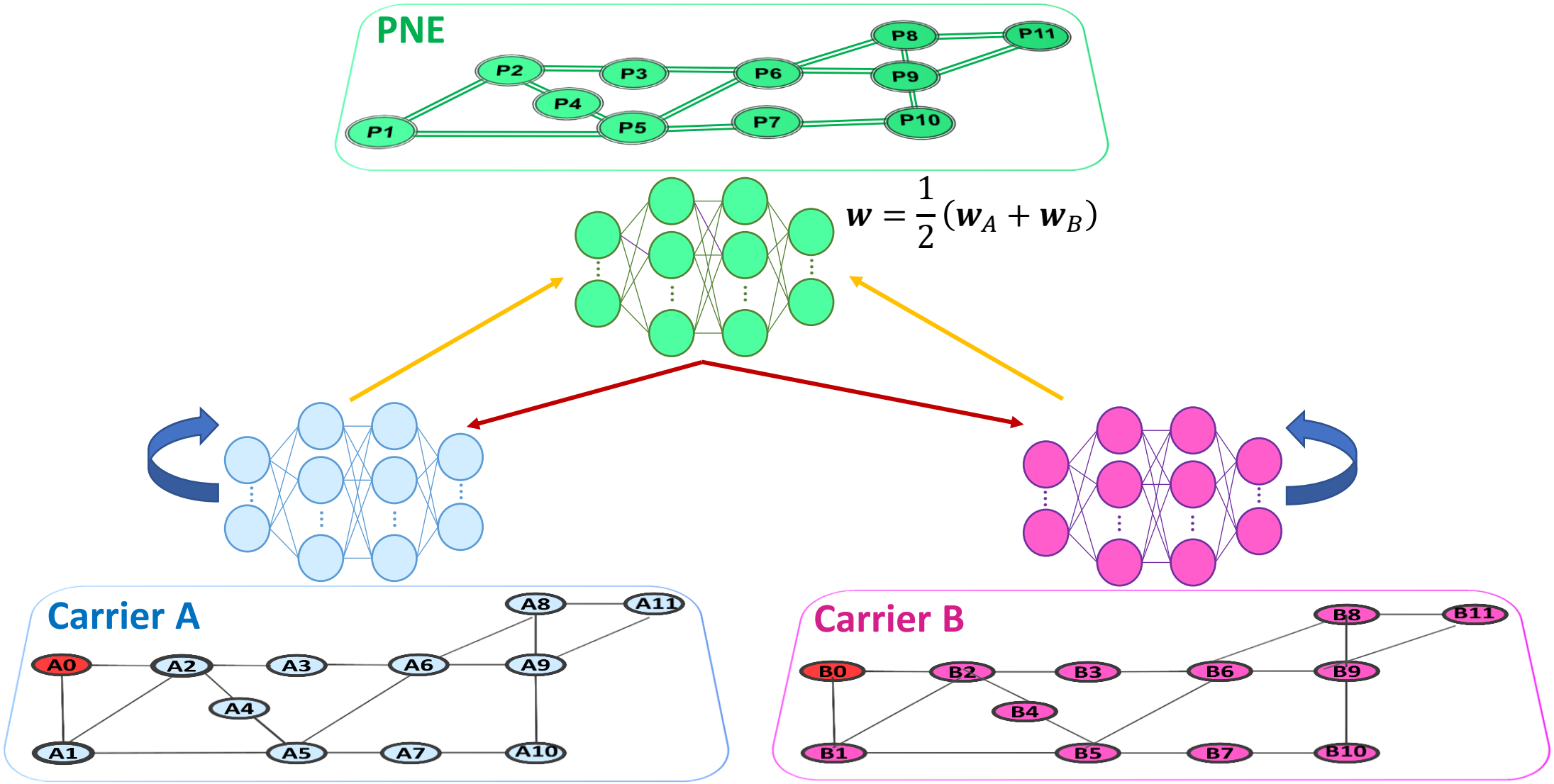

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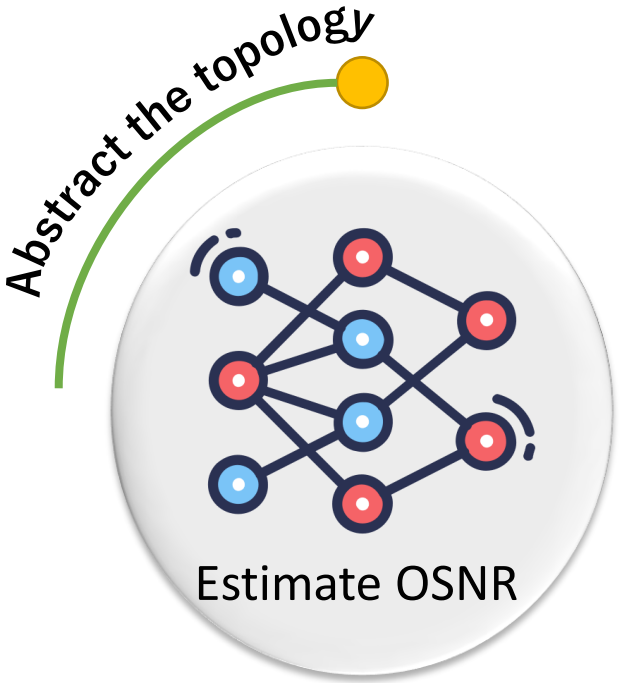
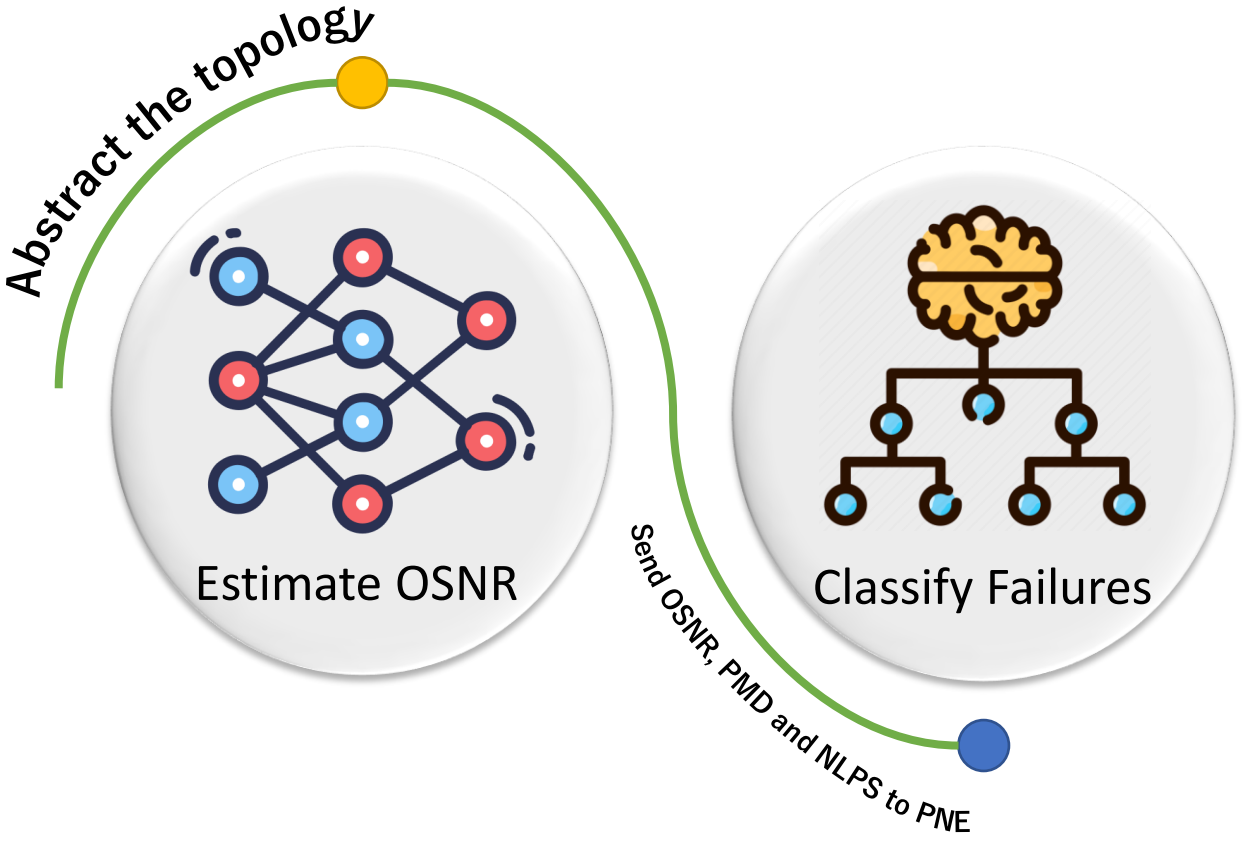
Flow of The Proposed Framework



The interconnection between different entities in the ecosystem

Flow of The Proposed Framework



Phase II: Classification

Danshi Wang, Chunyu Zhang, Wenbin Chen, Hui Yang, Min Zhang & Alan Pak Tao Lau, “A review of machine learning-based failure management in optical networks,” in *Science China Information Sciences*, vol. 65, no. 211302, 2022.

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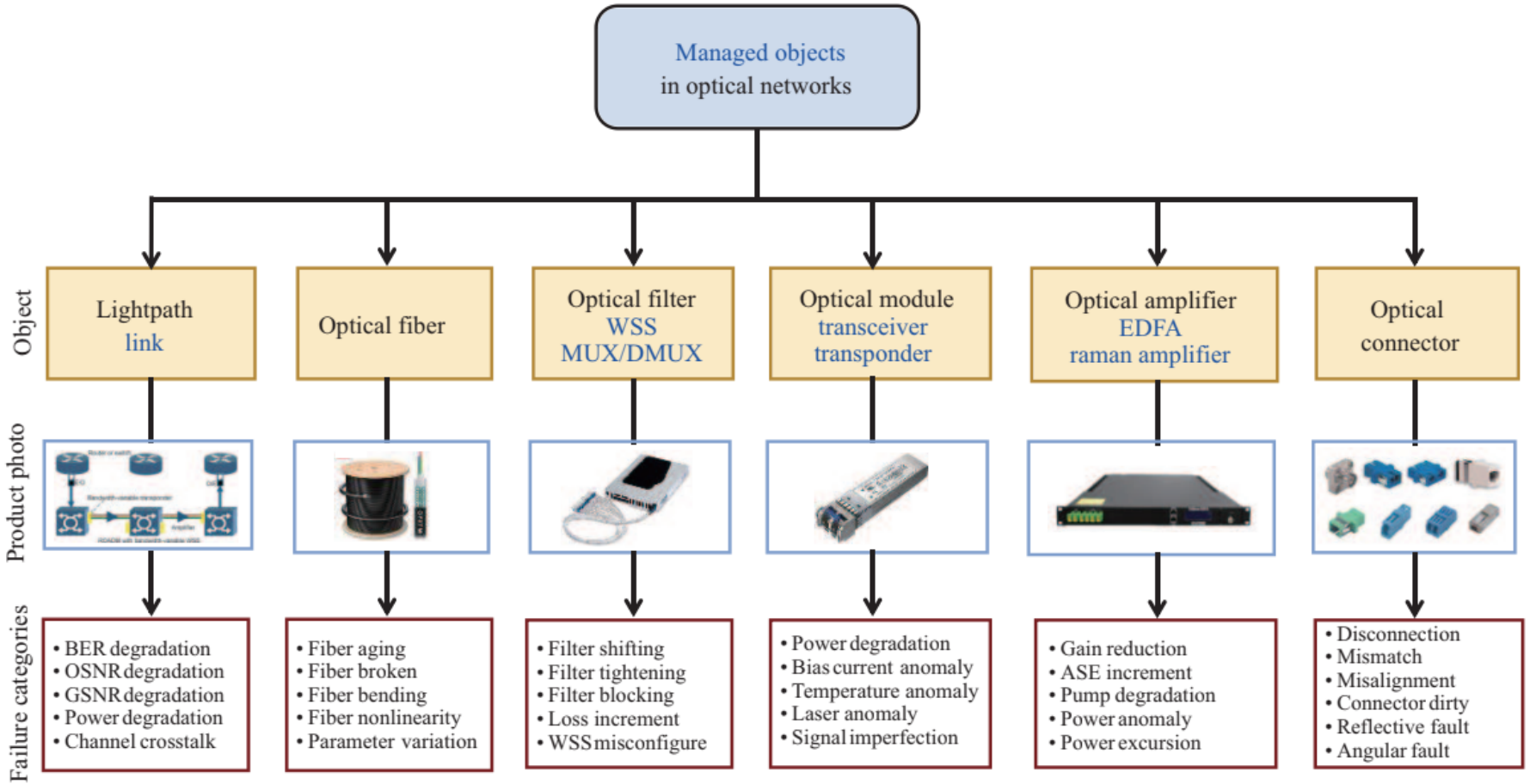

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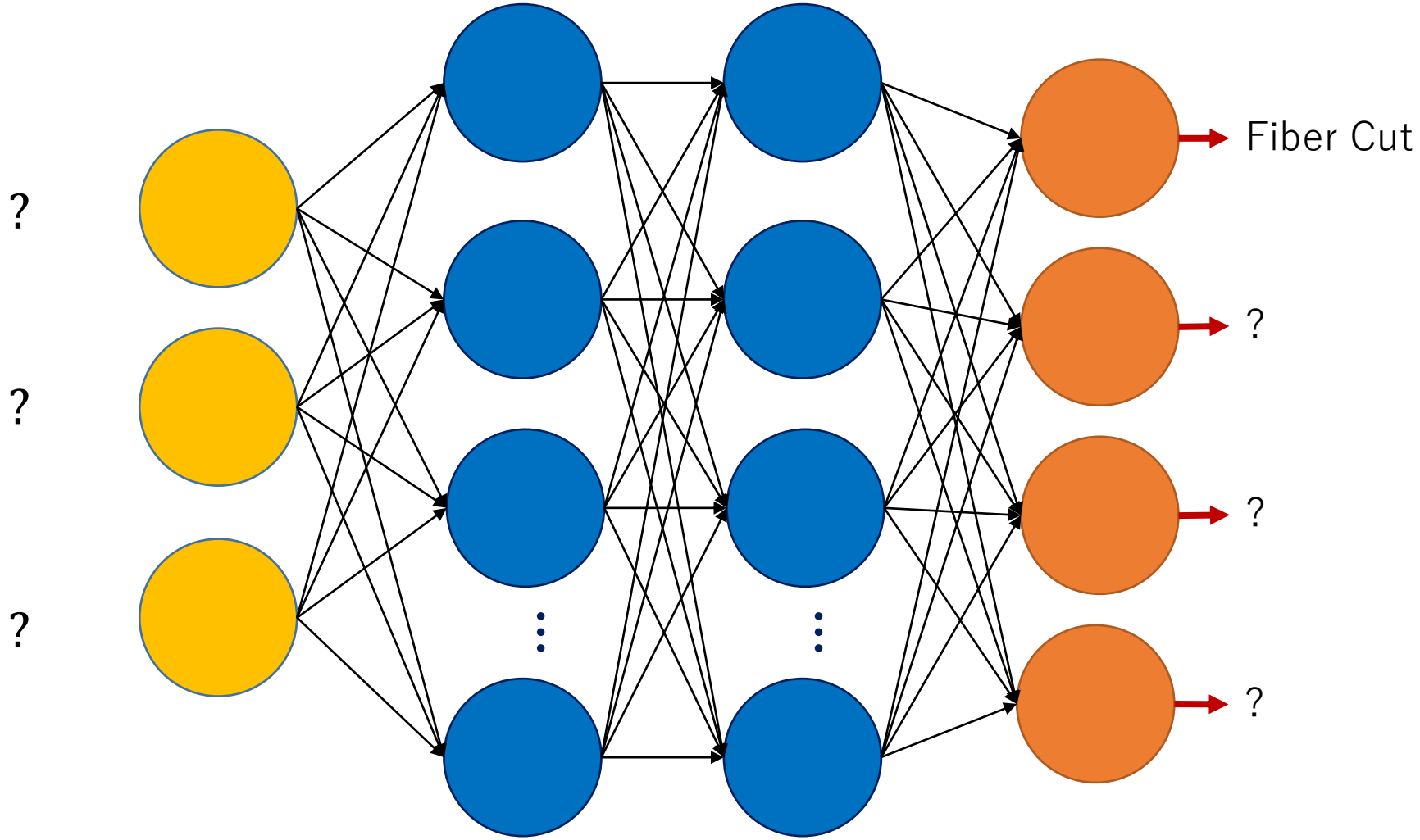

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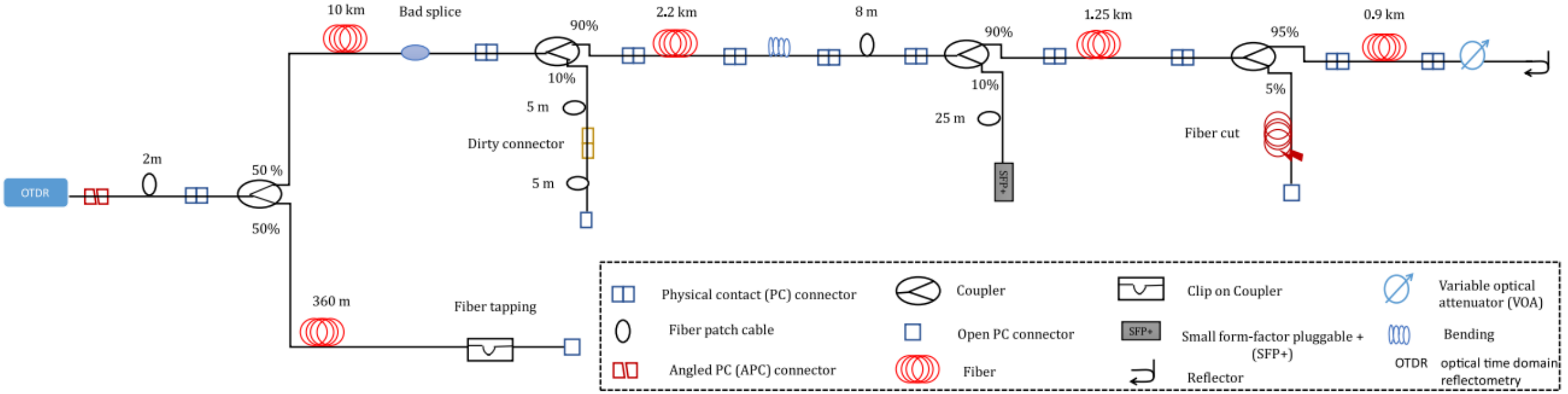

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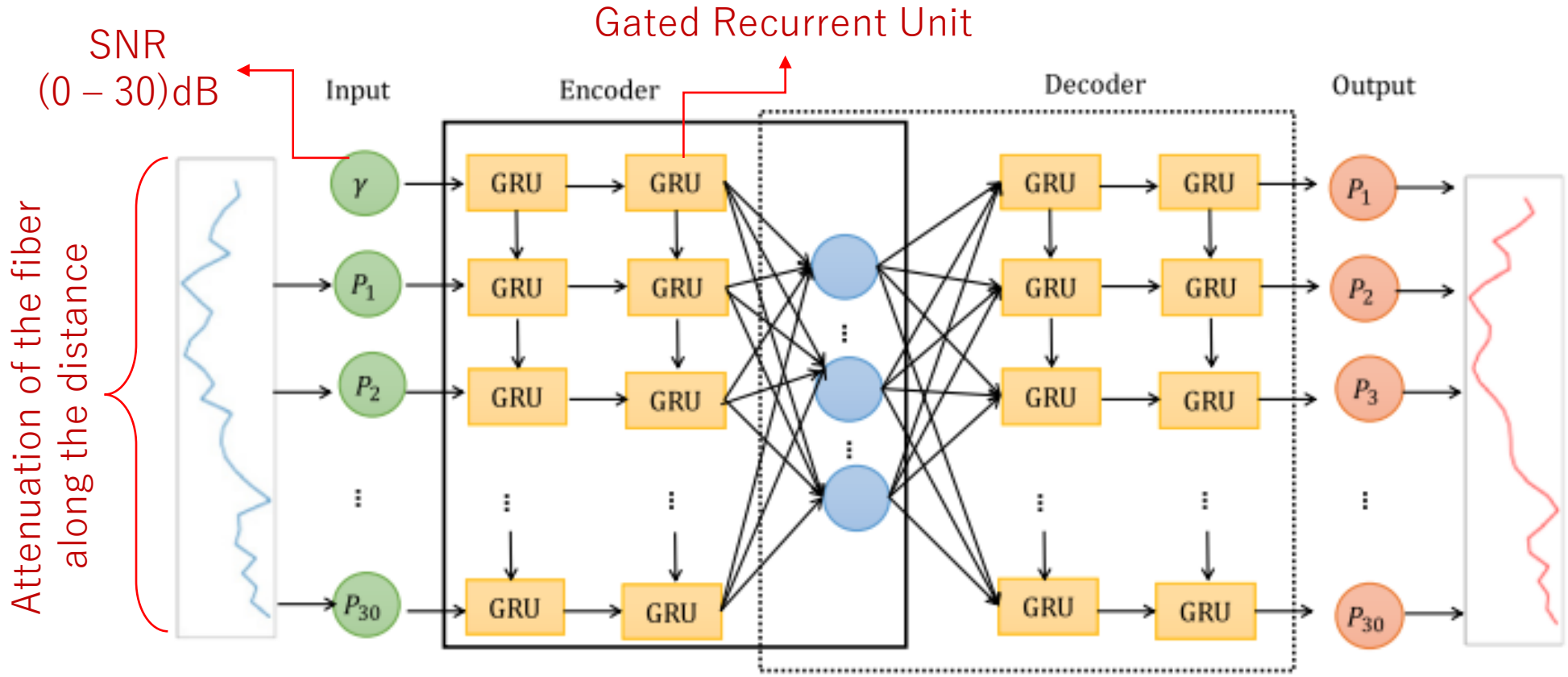

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Phase II: Classification

0	1	2	3	4	5	6	7
Normal	Fiber Tapping	Bad Splice	Bending Event	Dirty Connector	Fiber Cut	PC Connector	Reflector

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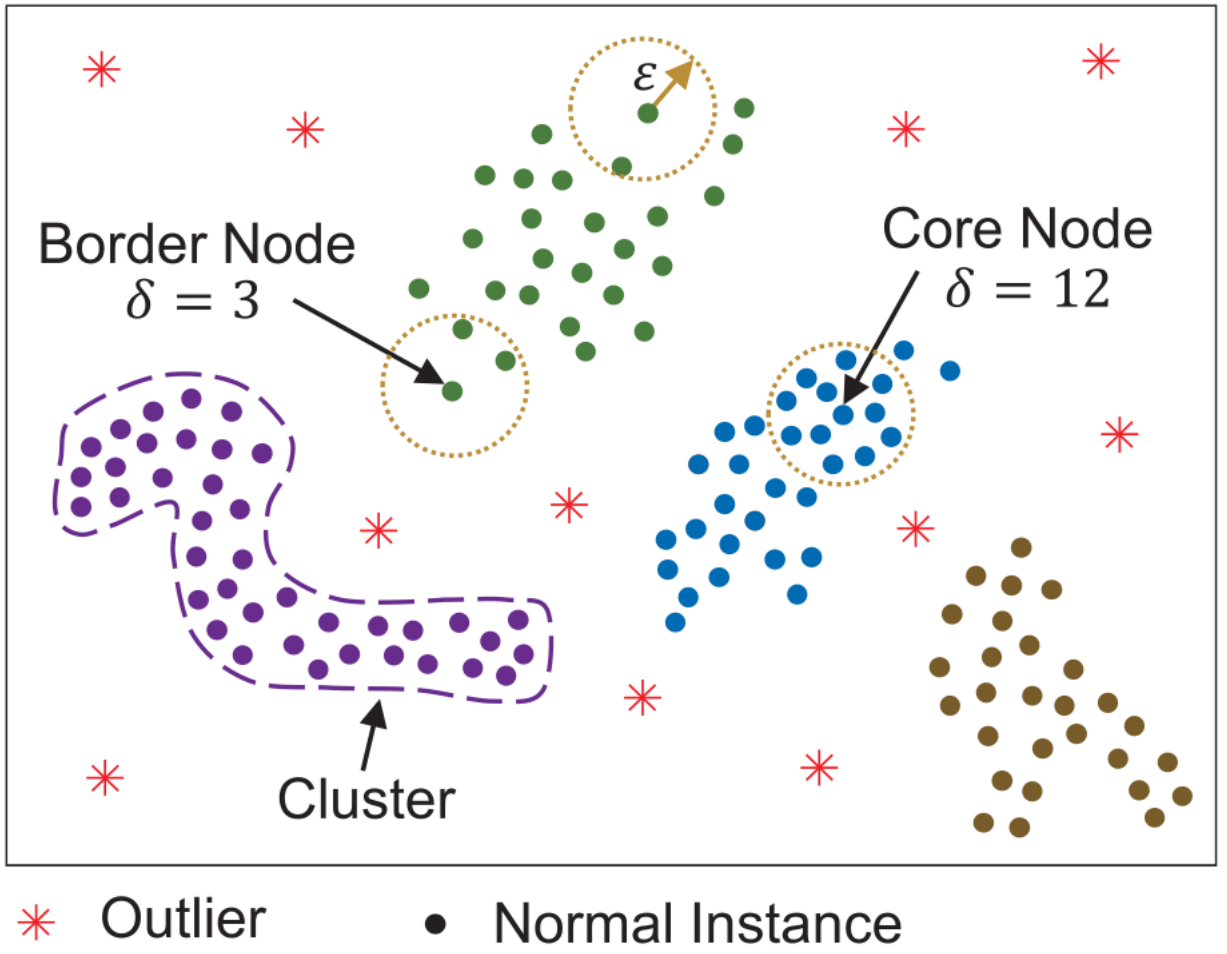

X. Chen, B. Li, R. Proietti, Z. Zhu and S. J. B. Yoo, "Self-Taught Anomaly Detection With Hybrid Unsupervised/Supervised Machine Learning in Optical Networks," in Journal of Lightwave Technology, vol. 37, no. 7, pp. 1742-1749, 1 April1, 2019.

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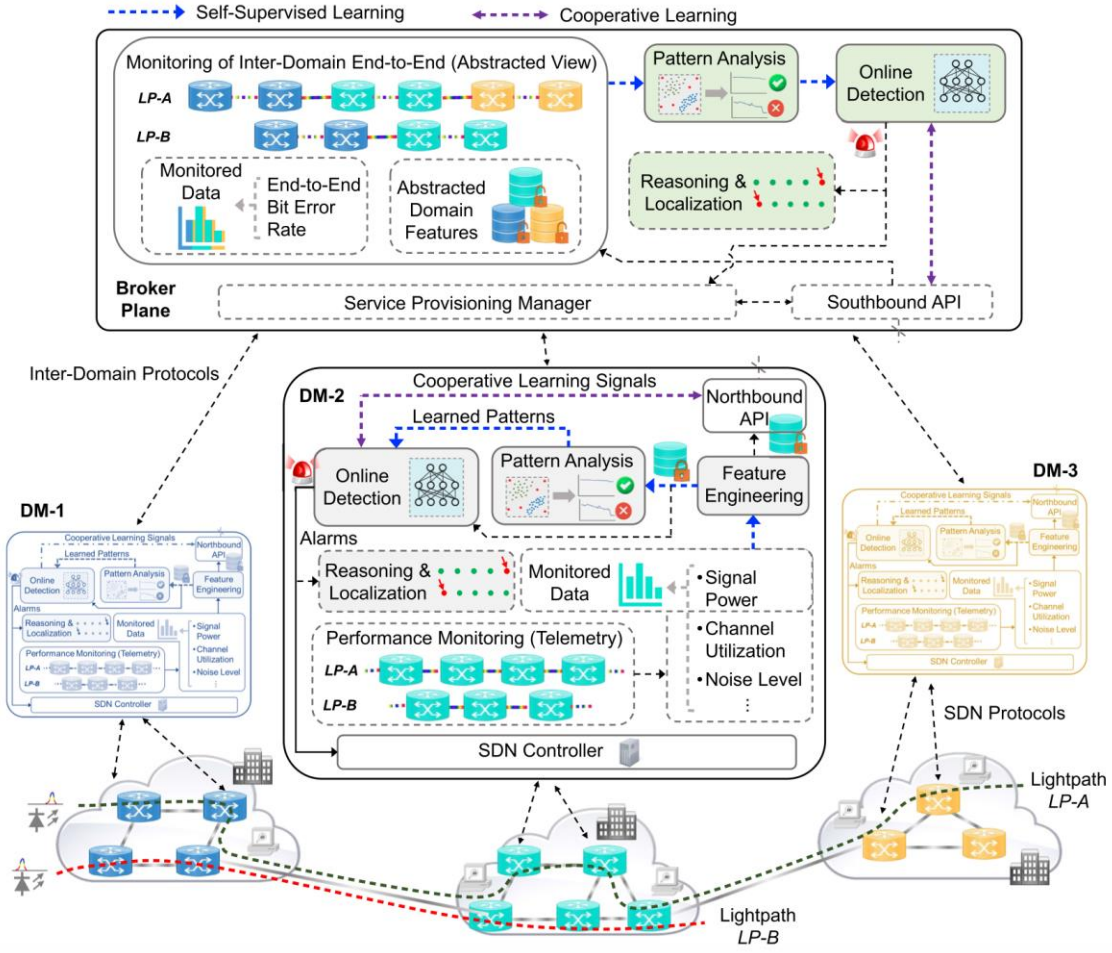

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The interconnection between different entities in the ecosystem

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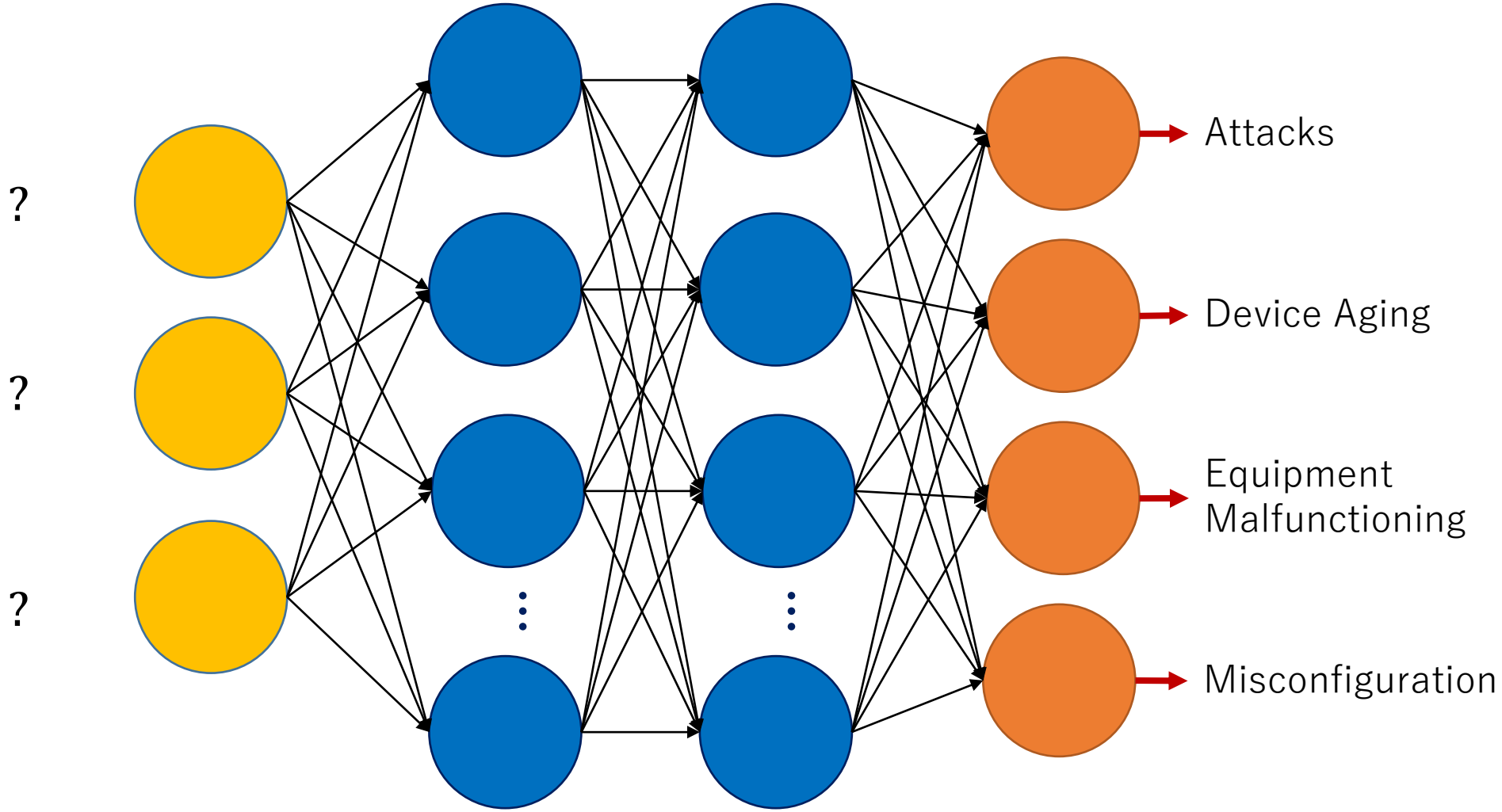
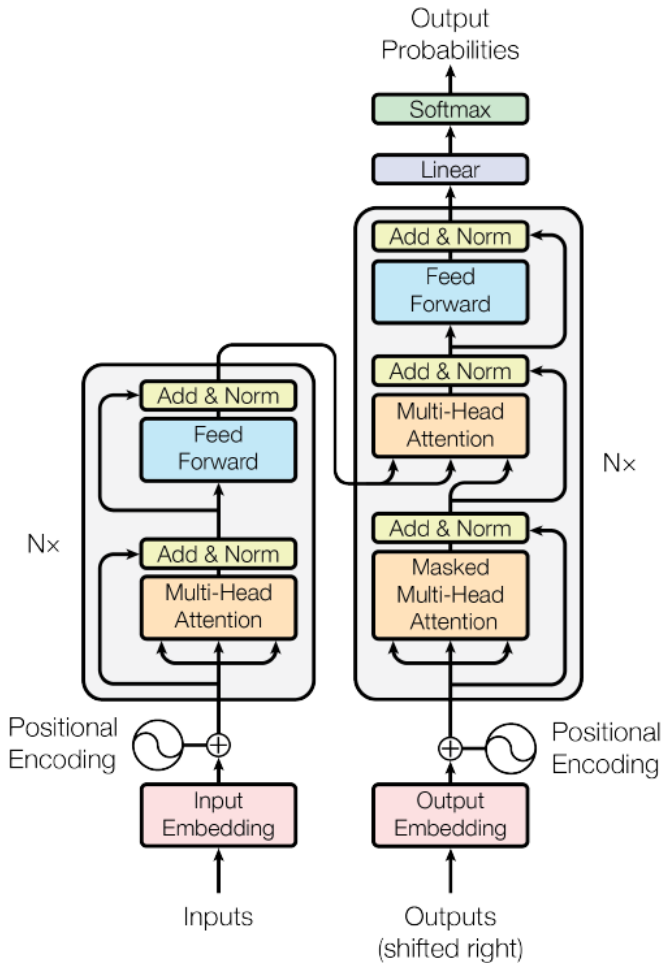


Phase II: Transformer Neural Networks



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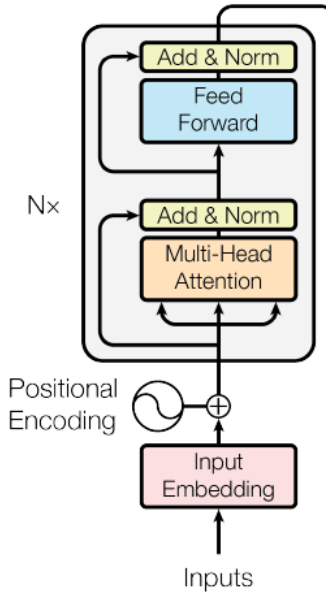

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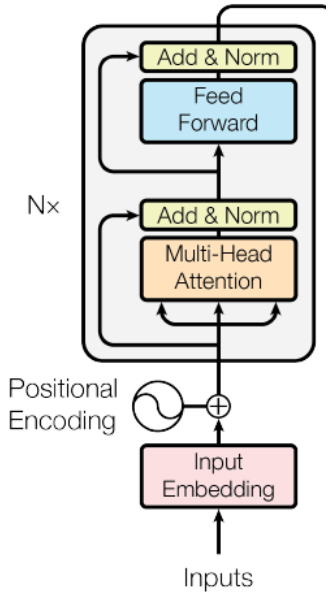
Bark is very cute and he is a dog



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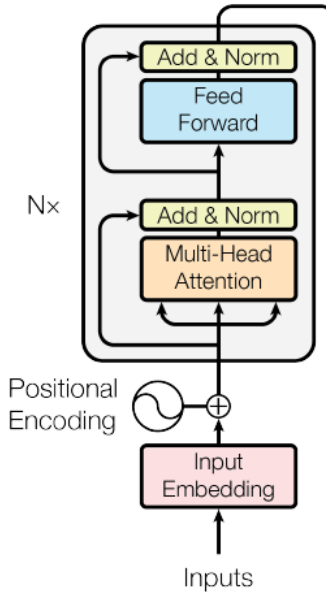

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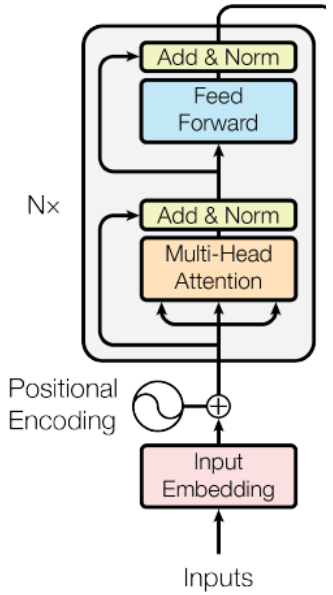

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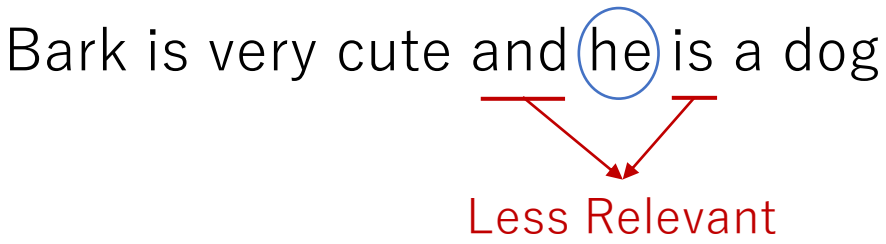

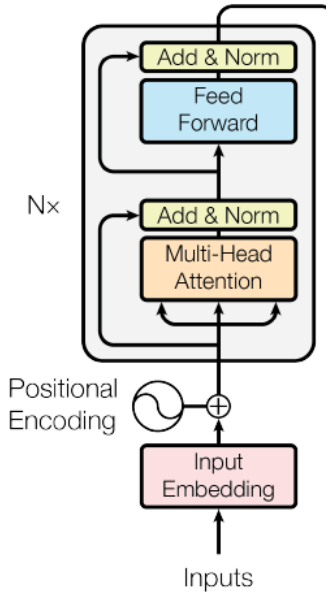

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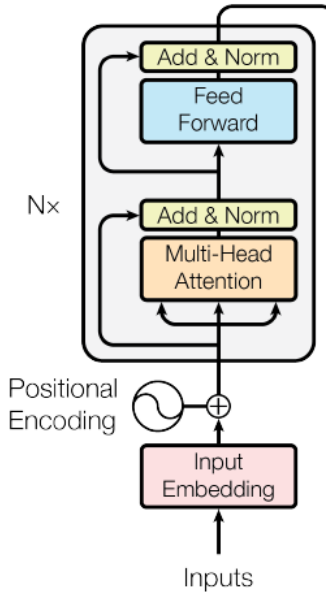
Less Relevant



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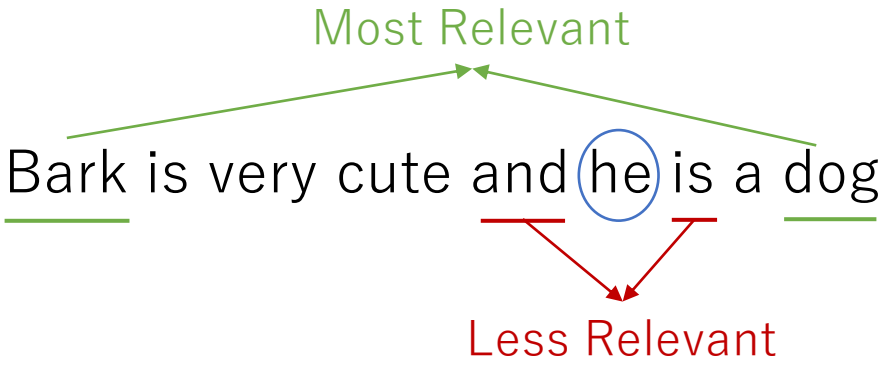

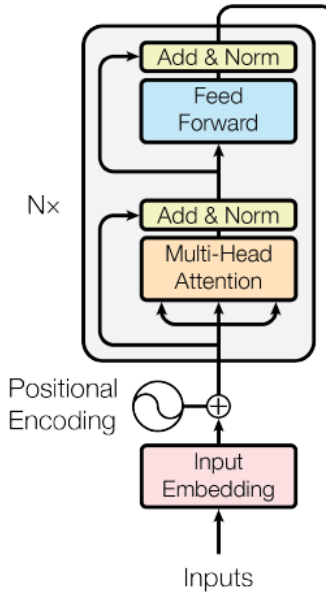

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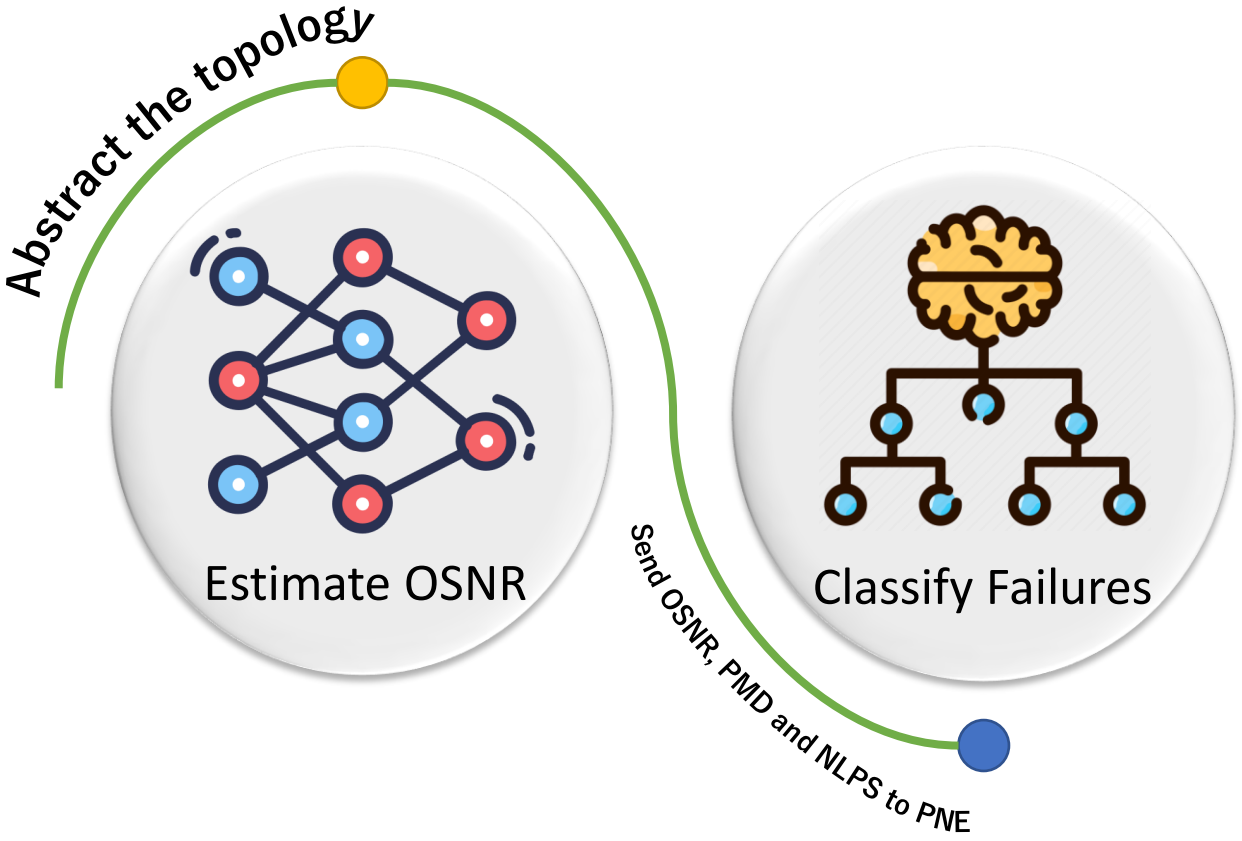
Flow of The Proposed Framework



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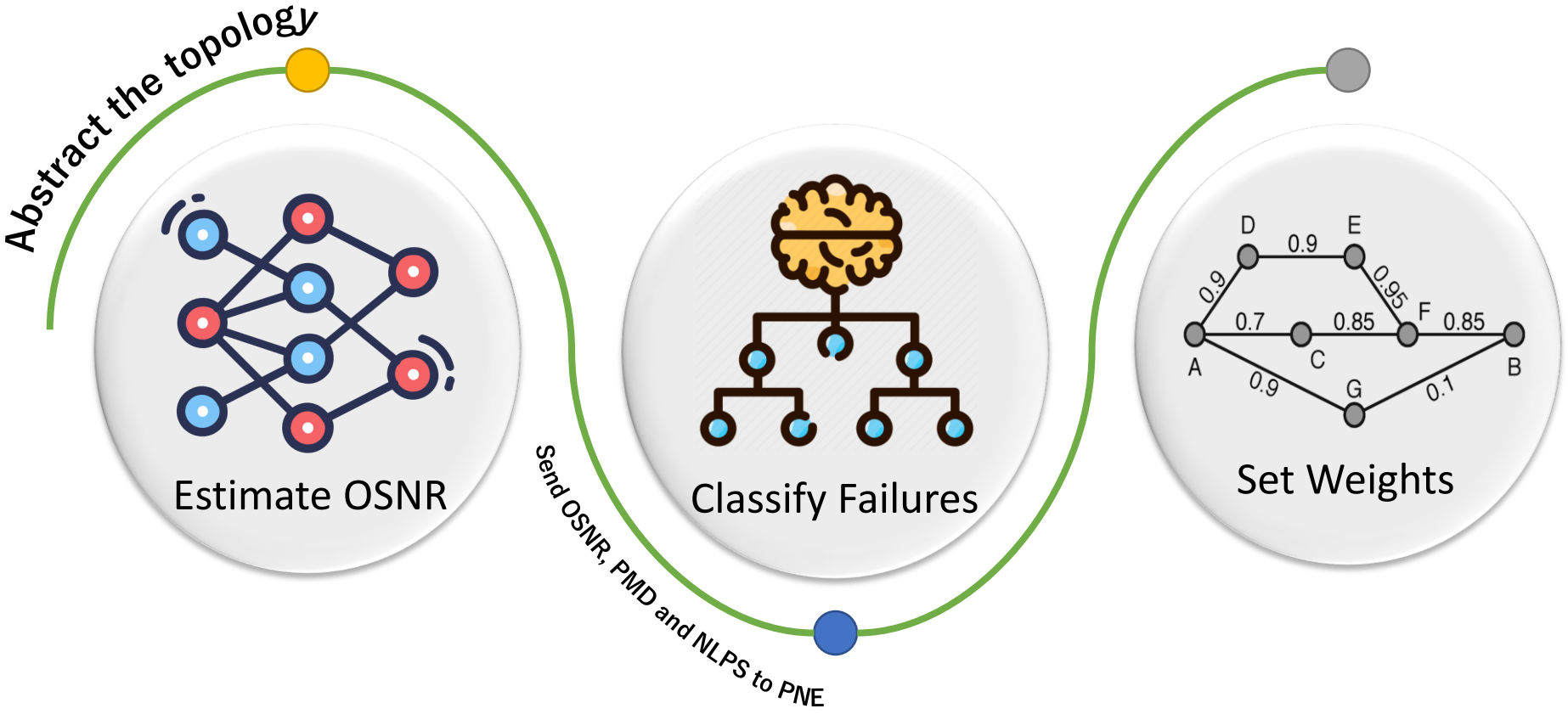
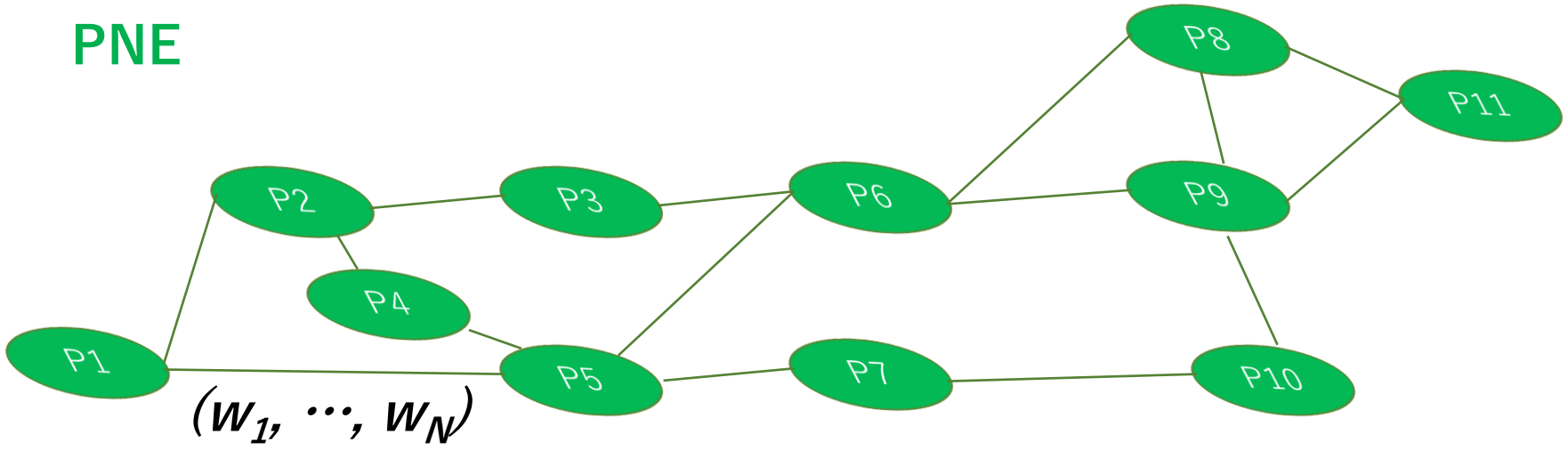
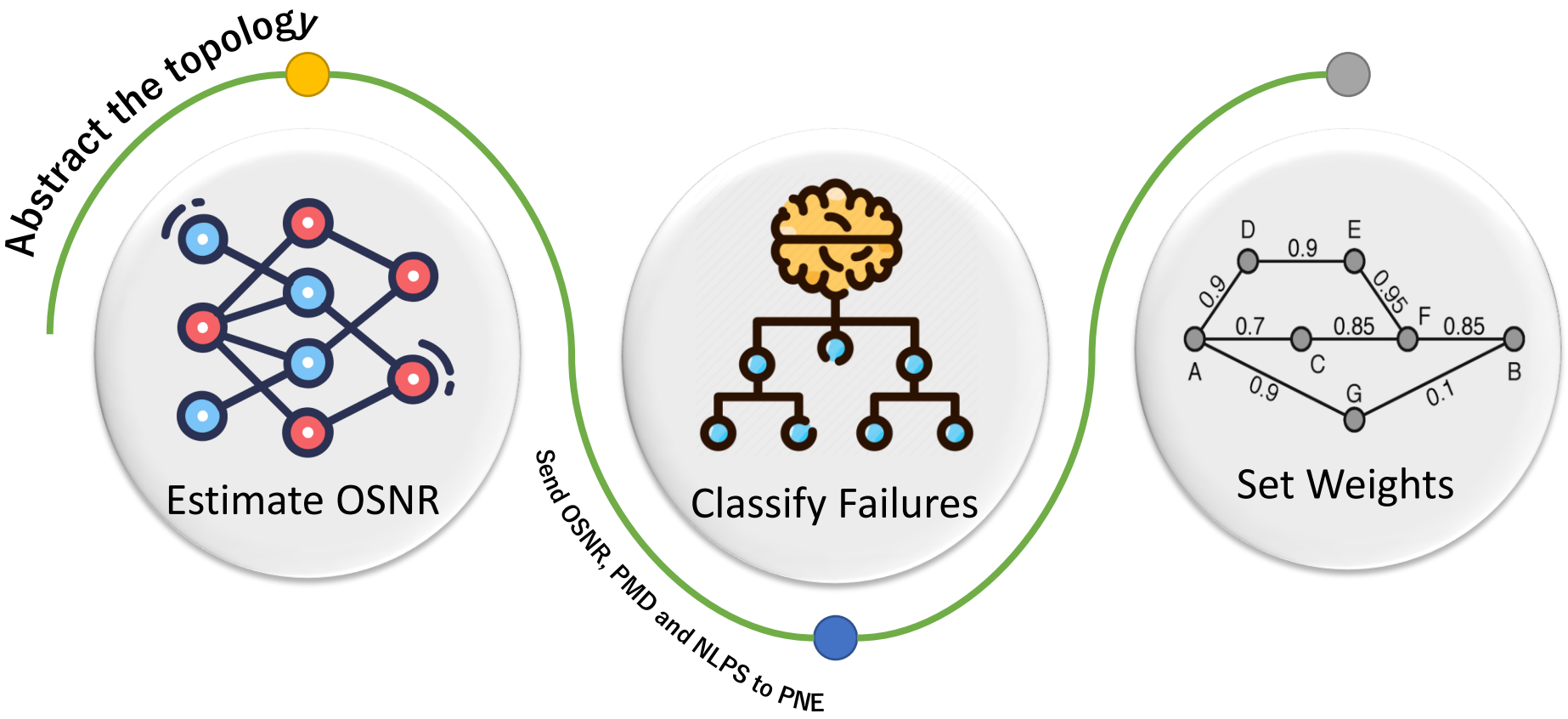


Setting Weights



Link	Weight	Link	Weight	Link	Weight	Link	Weight
(P1-P2)	$(w_1, \cdots, w_N)$	(P3-P6)	$(w_1, \cdots, w_N)$	(P6-P8)	$(w_1, \cdots, w_N)$	(P8-P11)	$(w_1, \cdots, w_N)$
(P1-P5)	$(w_1, \cdots, w_N)$	(P4-P5)	$(w_1, \cdots, w_N)$	(P6-P9)	$(w_1, \cdots, w_N)$	(P9-P10)	$(w_1, \cdots, w_N)$
(P2-P3)	$(w_1, \cdots, w_N)$	(P5-P6)	$(w_1, \cdots, w_N)$	(P7-P10)	$(w_1, \cdots, w_N)$	(P9-P11)	$(w_1, \cdots, w_N)$
(P2-P4)	$(w_1, \cdots, w_N)$	(P5-P7)	$(w_1, \cdots, w_N)$	(P8-P9)	$(w_1, \cdots, w_N)$		

Flow of The Proposed Framework



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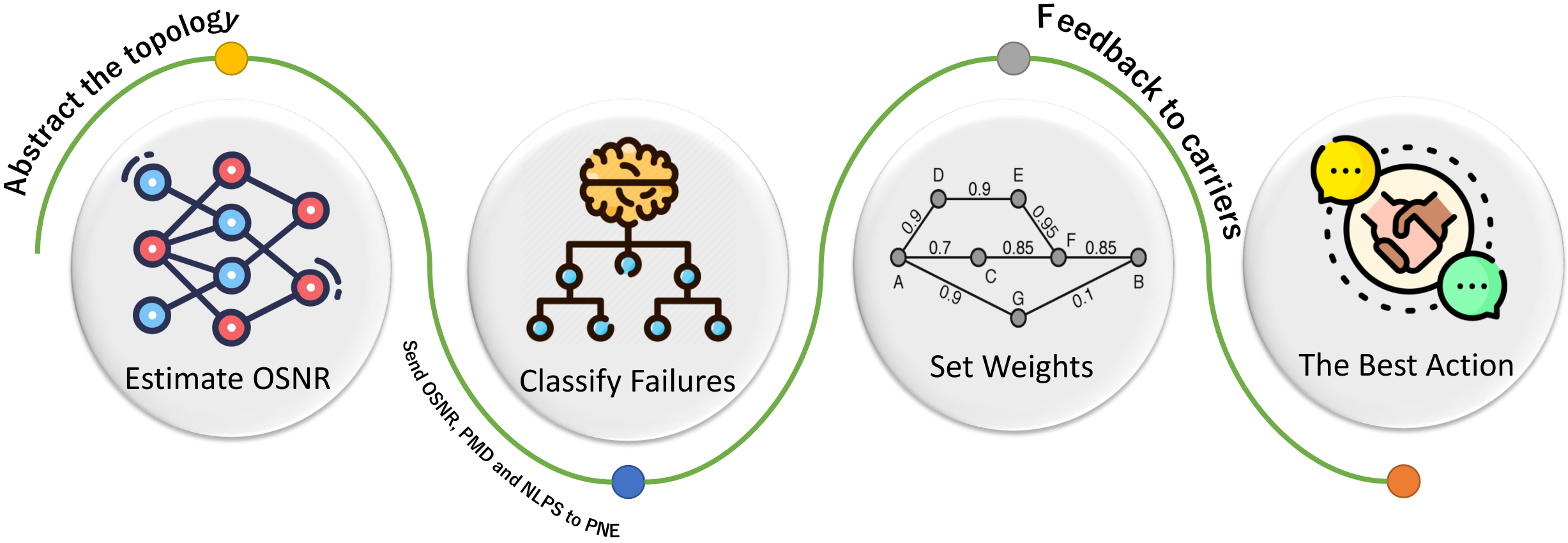

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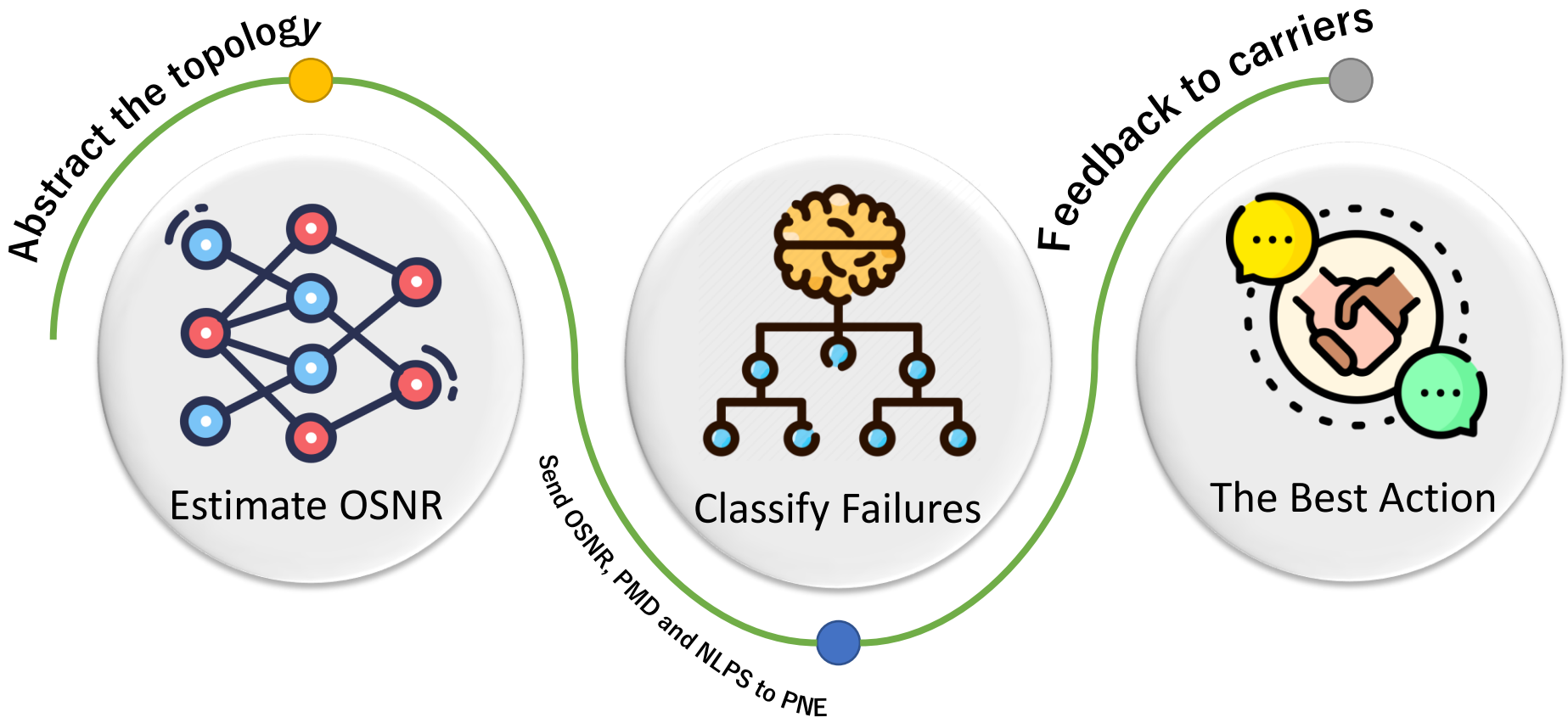

Phase III: Providing Carriers with Suggestions

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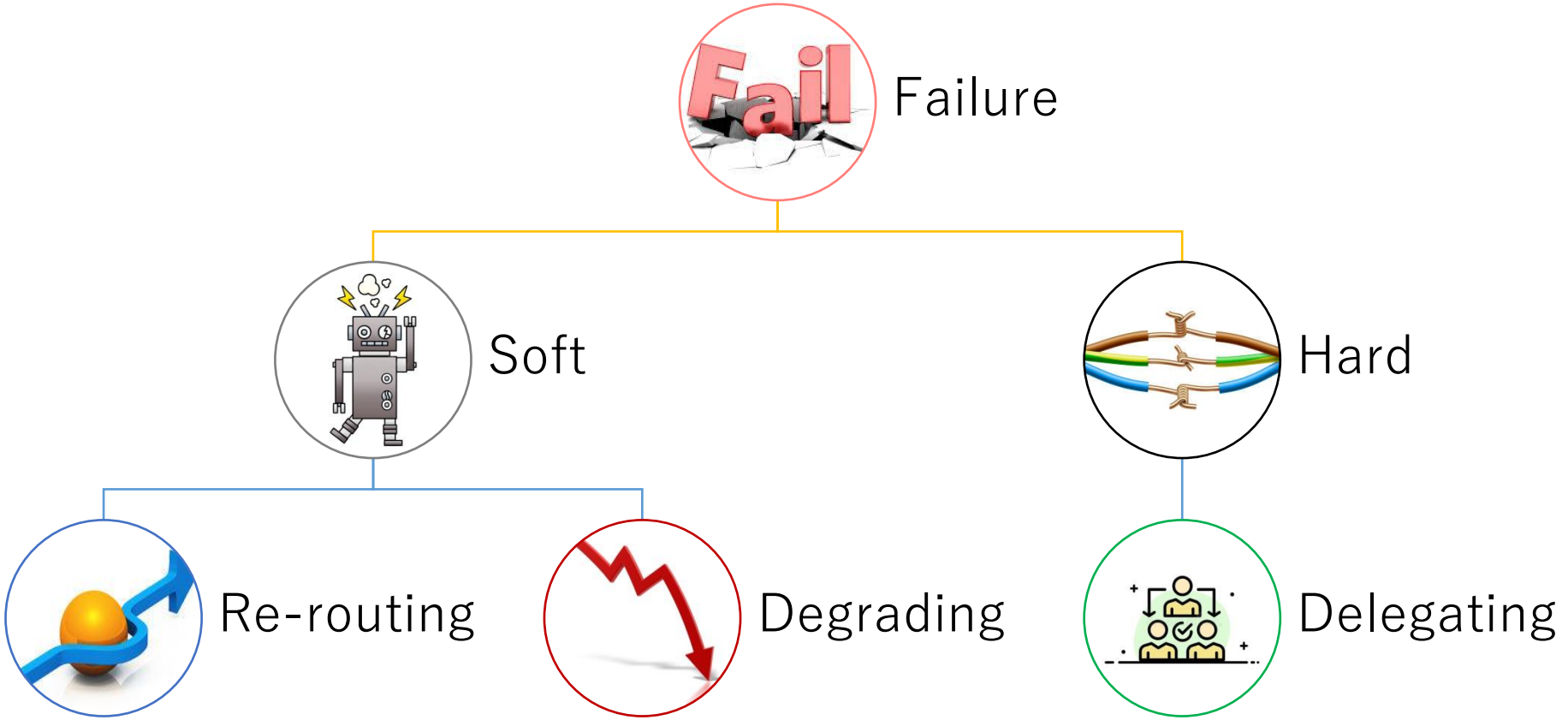

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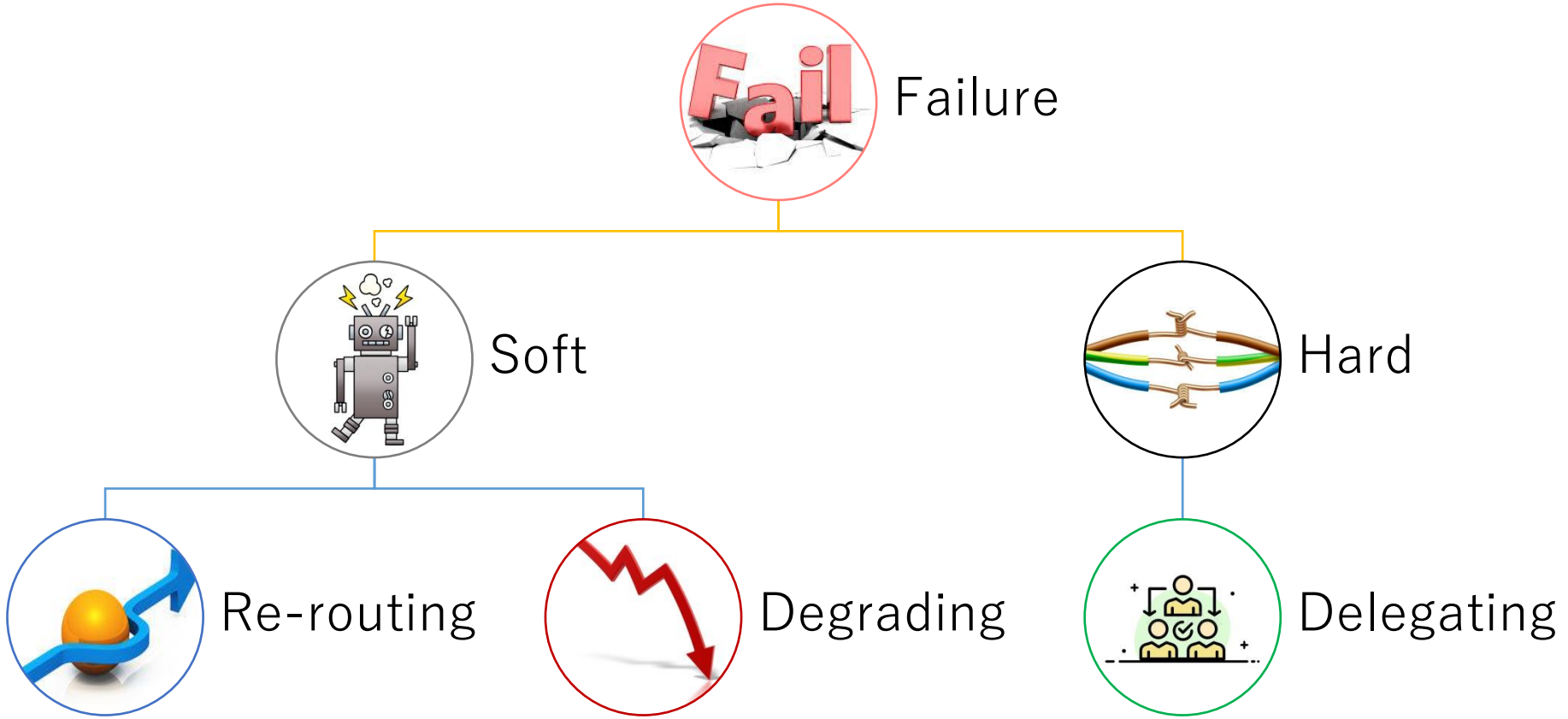

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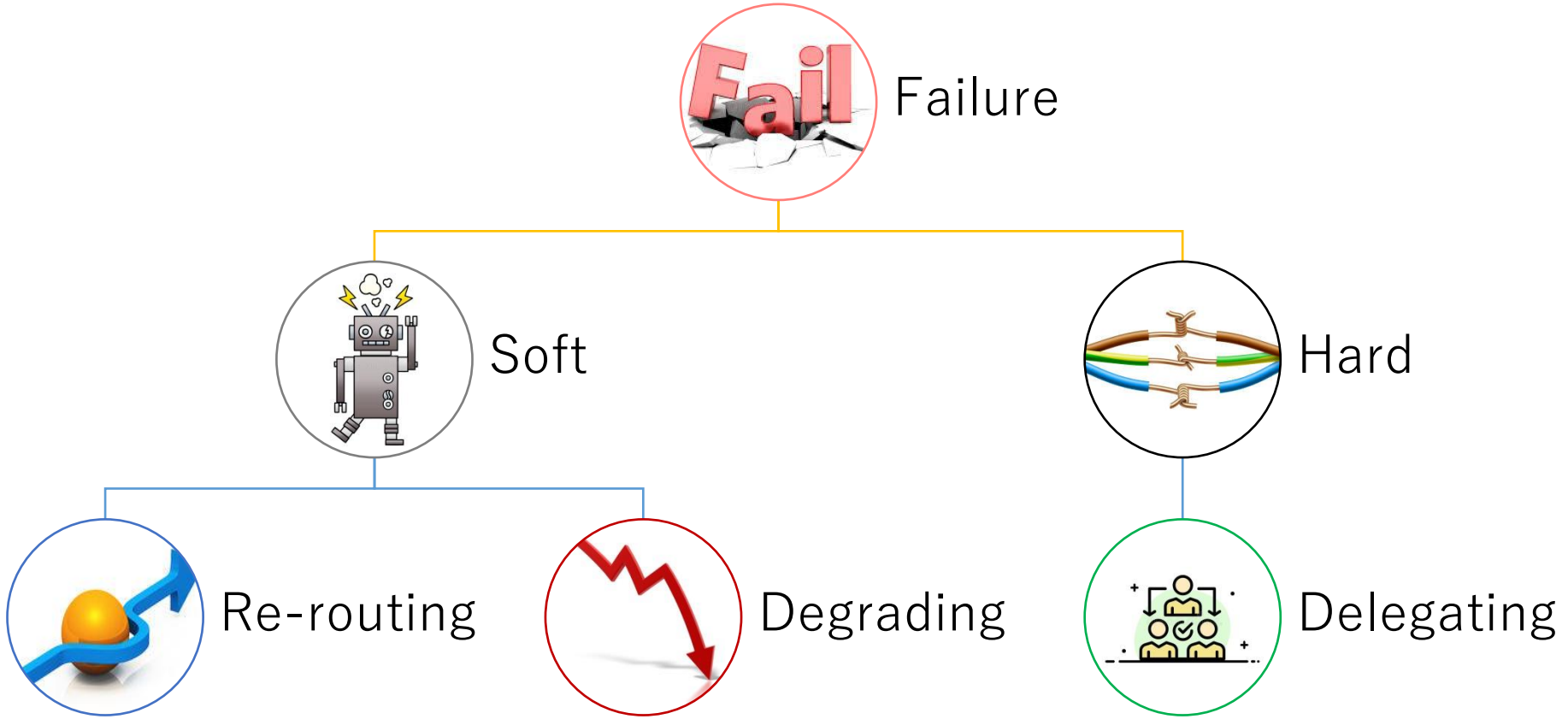

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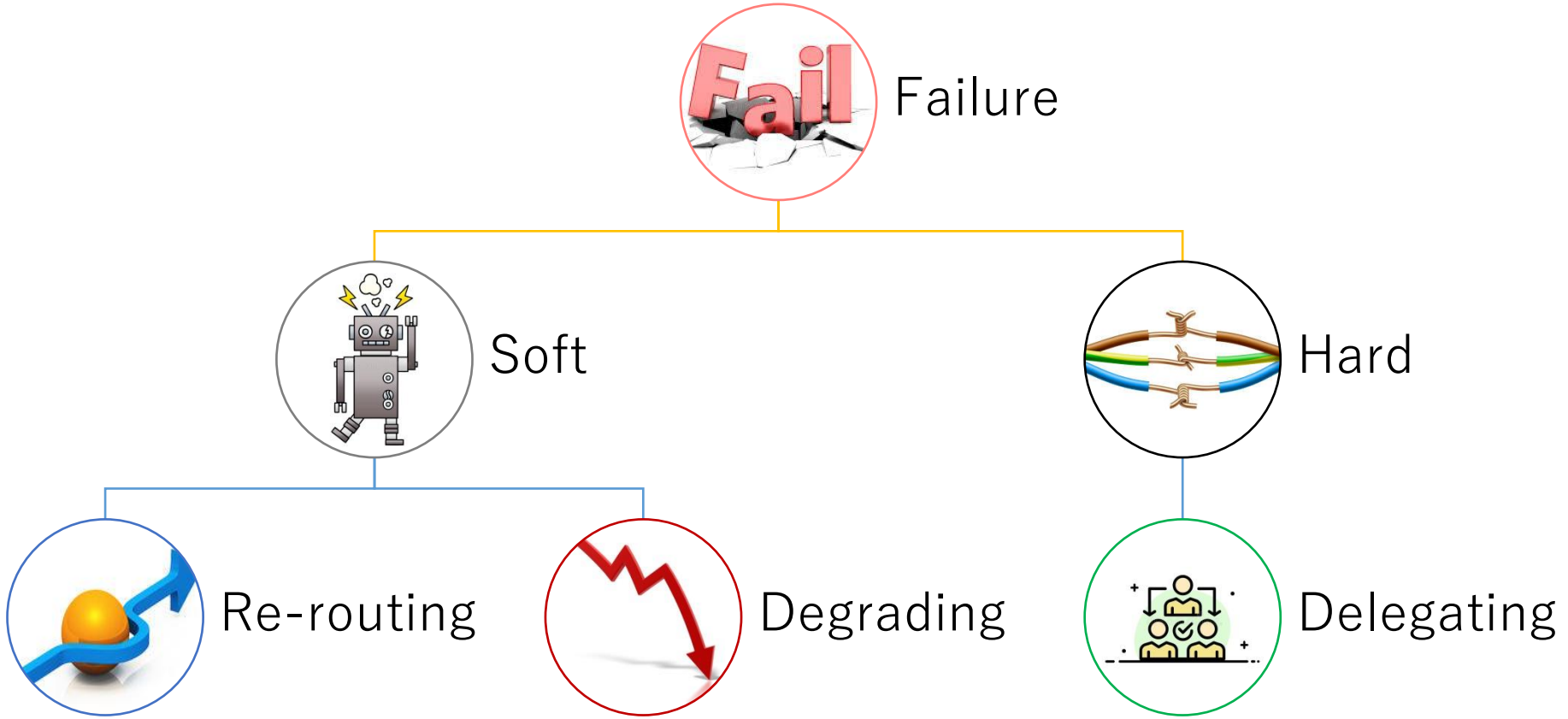

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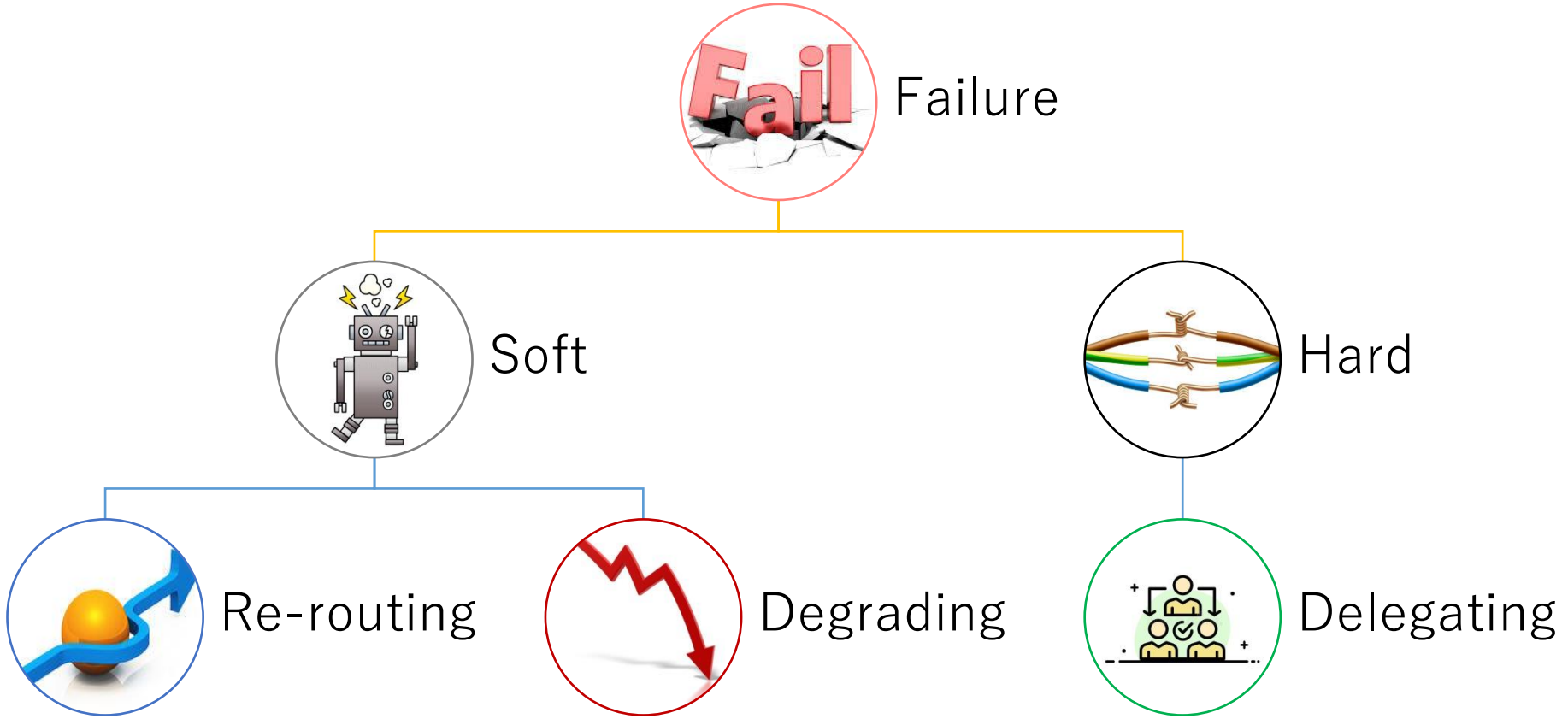

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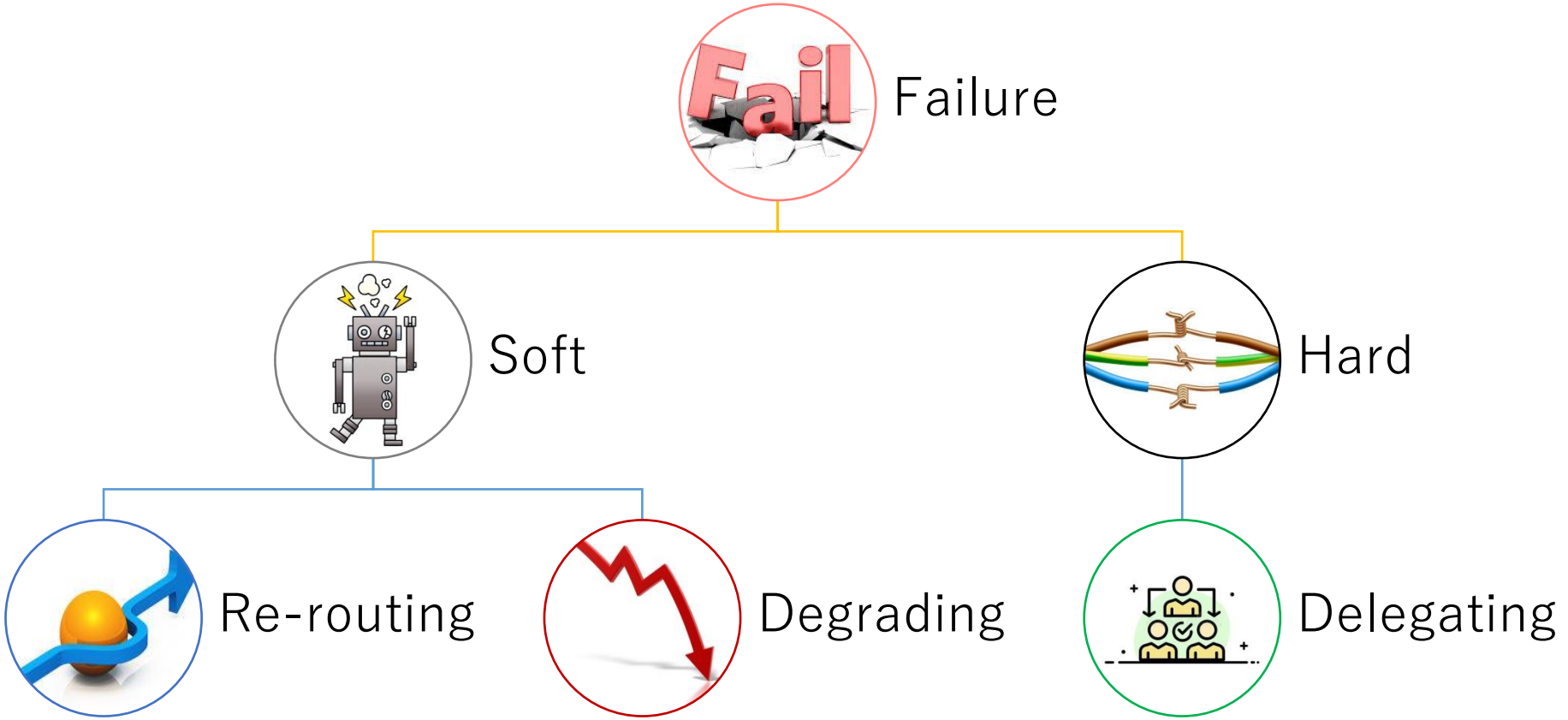

Phase III: Negotiation

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PNE	Carrier	DCP	ISP
• Enhance ecosystem survivability • Prolong ecosystem lifetime • Optimal resource management	• Reduce burden (resource crunch) • Reduce recovery cost	• Lower cost • Higher service restoration	• Lower cost • Higher service restoration

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