An Untold Story of Redundant Clouds: Making Your Service Deployment Truly Reliable

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Road-Map

- Motivations
- Goal & Insight
- iRec System
- Next Steps

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Background

- Application providers:
  - enjoy the simplicity of using the clouds

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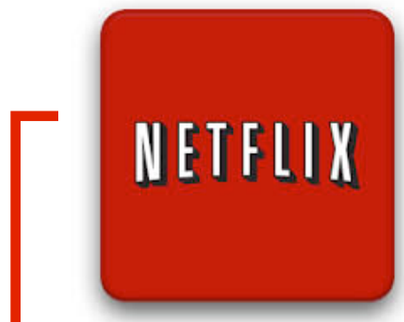
Background

- Application providers:
  - enjoy the simplicity of using the clouds
  - have no idea about what happen in the clouds
  - rent multiple clouds for redundancy

Example 1: Netflix



Netflix Application Service | **App**

EC2 availability zone

EC2 availability zone

EC2 availability zone

IaaS

Example 2: iCloud

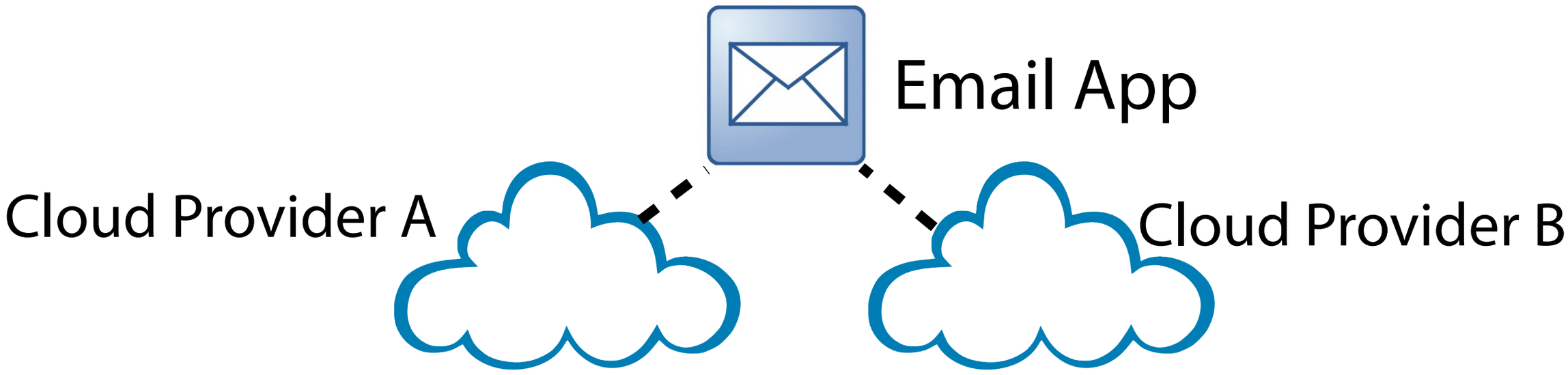
iCloud Application Service — **App**

Amazon EC2 Service

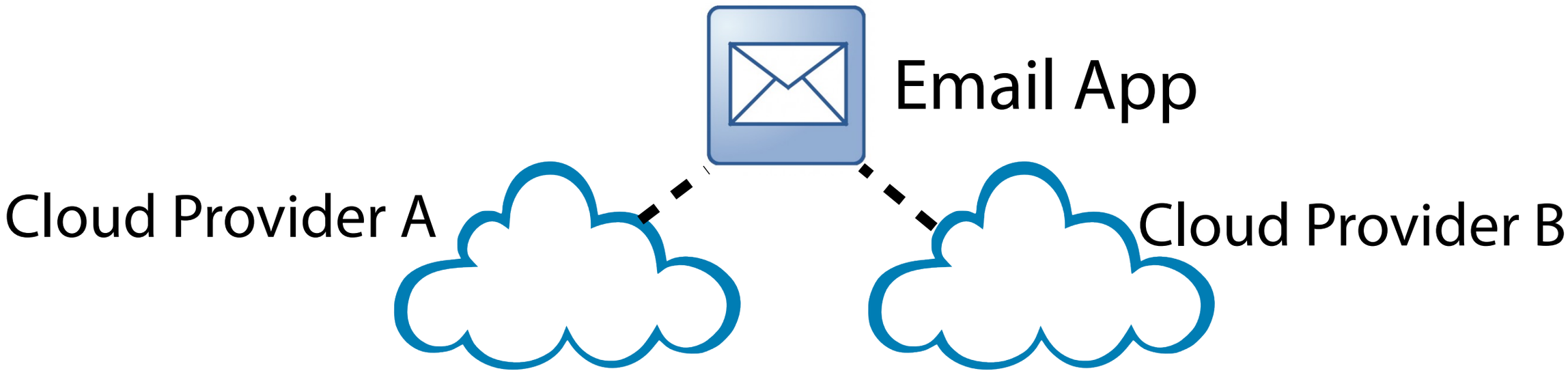
Microsoft Azure Service

IaaS

Problem

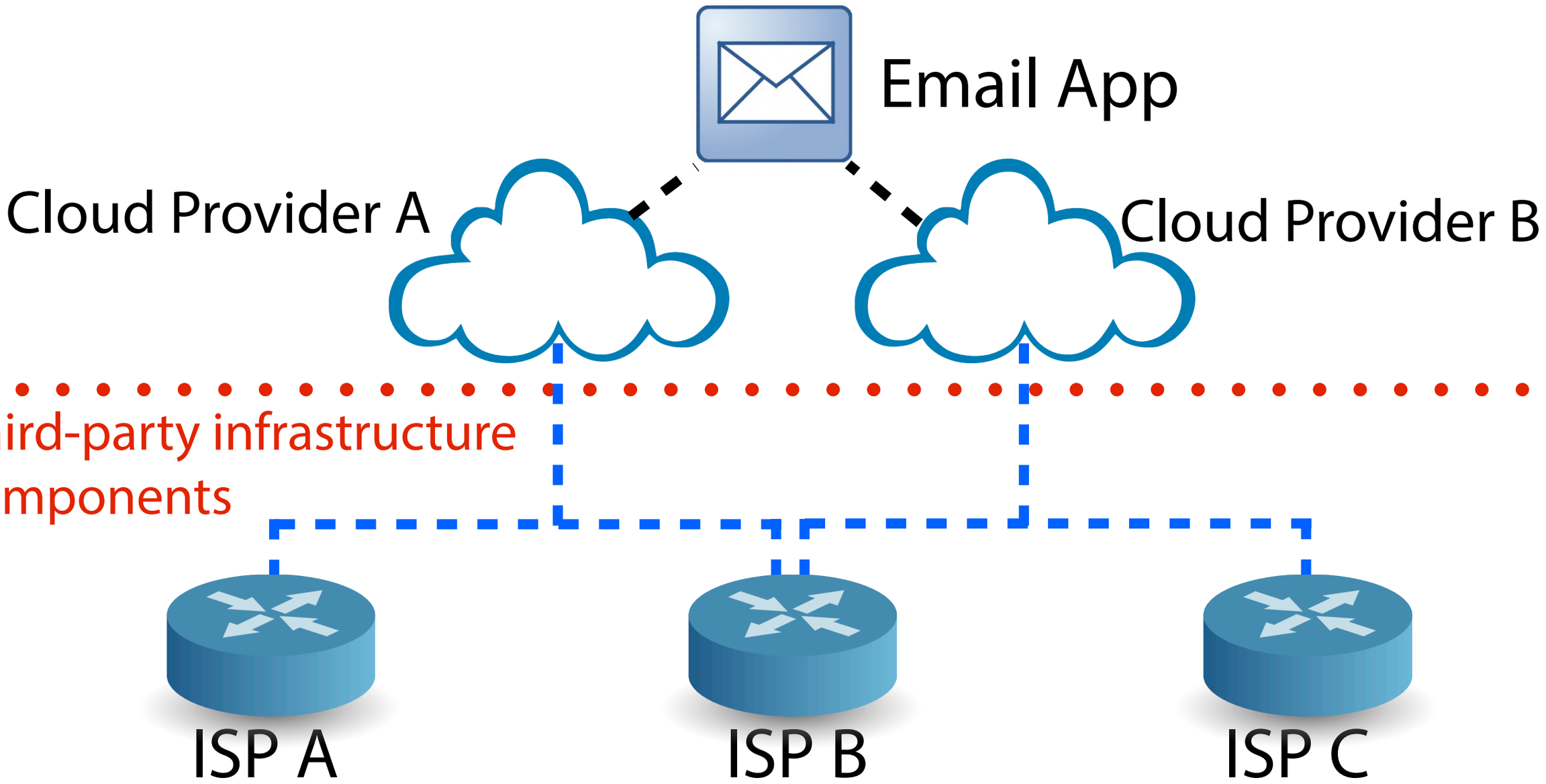


Problem

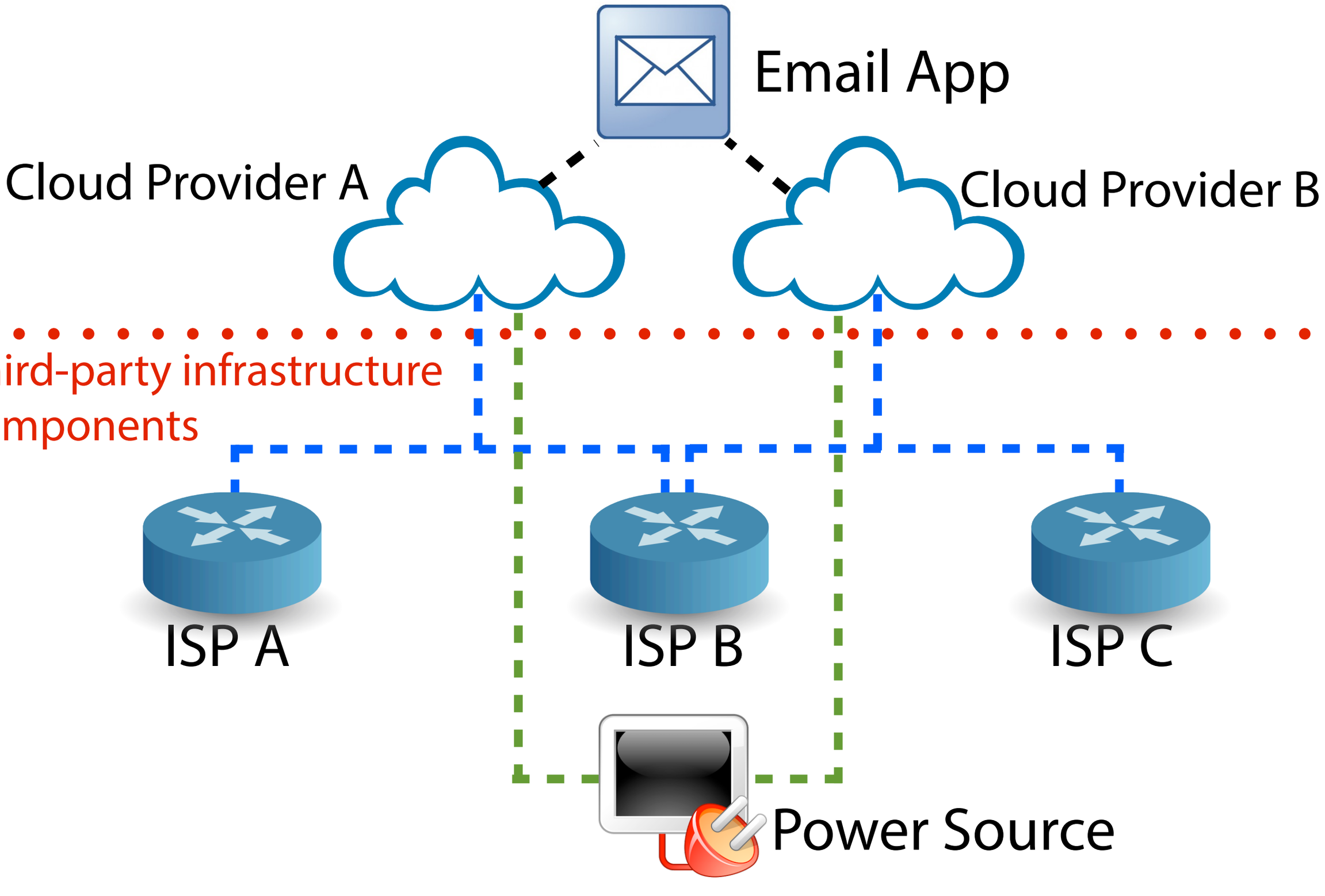


Third-party infrastructure components

Problem


Email App
Cloud Provider A
Cloud Provider B
Third-party infrastructure components
ISP A
ISP B
ISP C

Problem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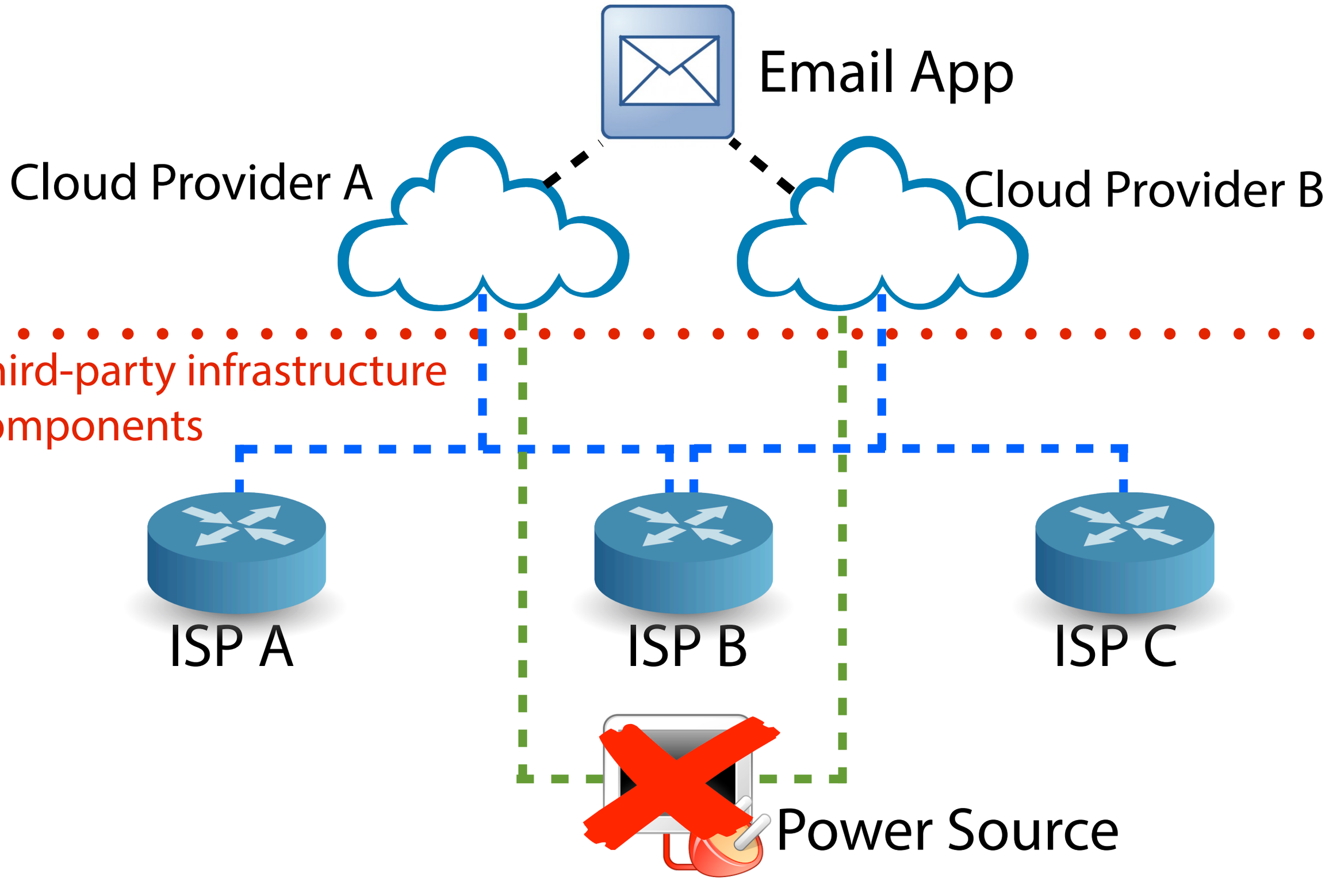
Power Source

Problem


Email App
Cloud Provider A
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ISP C
Power Source

Problem

Become unavailable !

Cloud Provider A

Cloud Provider B

Third-party infrastructure components

ISP A

ISP B

ISP C

Power Source

Problem

Lightning strikes Amazon's European cloud

Summary: *The lightning strike damaged a power company's transformer, causing disruption to Amazon Web Services's European cloud, and may have affected Microsoft's BPOS as well*

The outage, which Amazon Web Services (AWS) acknowledged on Sunday evening, affected its Dublin-based Elastic Compute Cloud (EC2) and Relational Database Service (RDS) cloud services, among others. The damage to the electricity infrastructure may have affected Microsoft's Business Productivity Online Services (BPOS) cloud as well, Microsoft said in a separate statement.

Existing Efforts

- Cloud providers allocate or tolerate failures via:
  - diagnosis systems, e.g., Sherlock.
  - fault-tolerant systems, e.g., F10, Skute.

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- We want to prevent the problem before the outage occurs
- Recommending truly independent redundancy services when deploying applications

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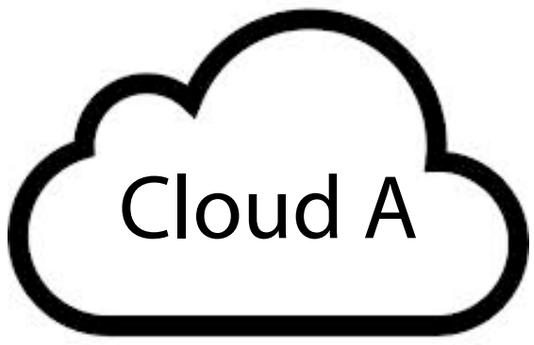
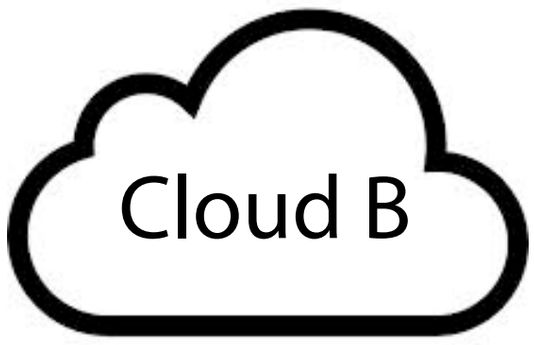
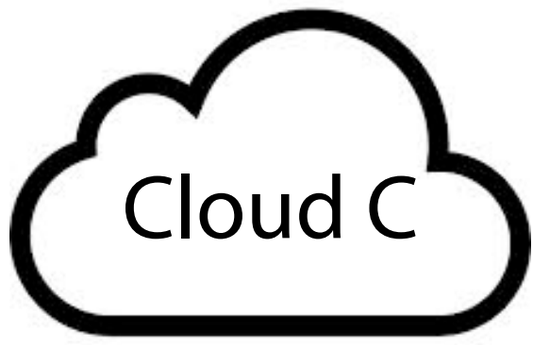
Goal & Insight

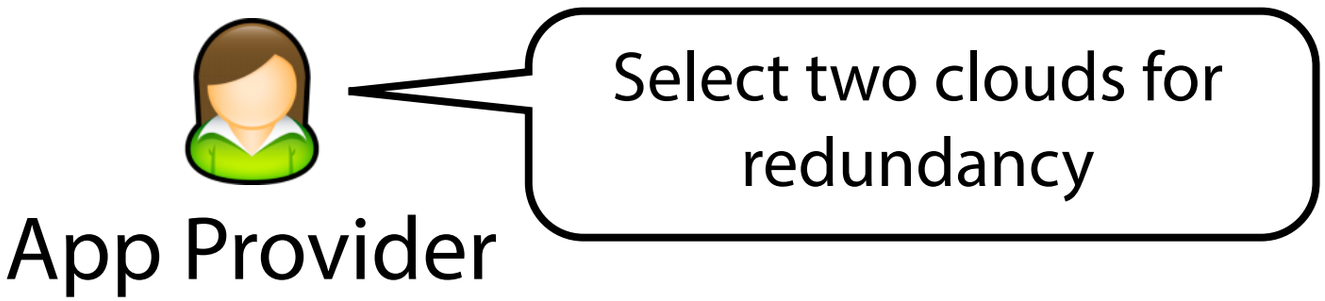
App Provider

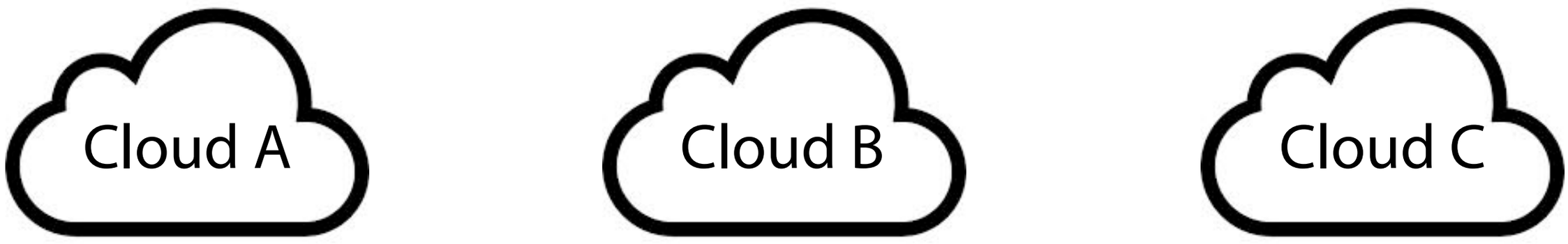




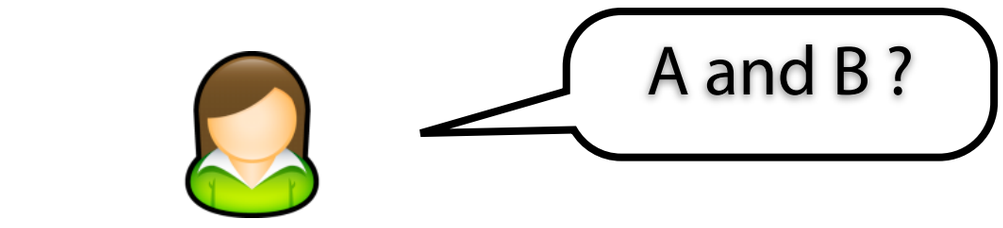


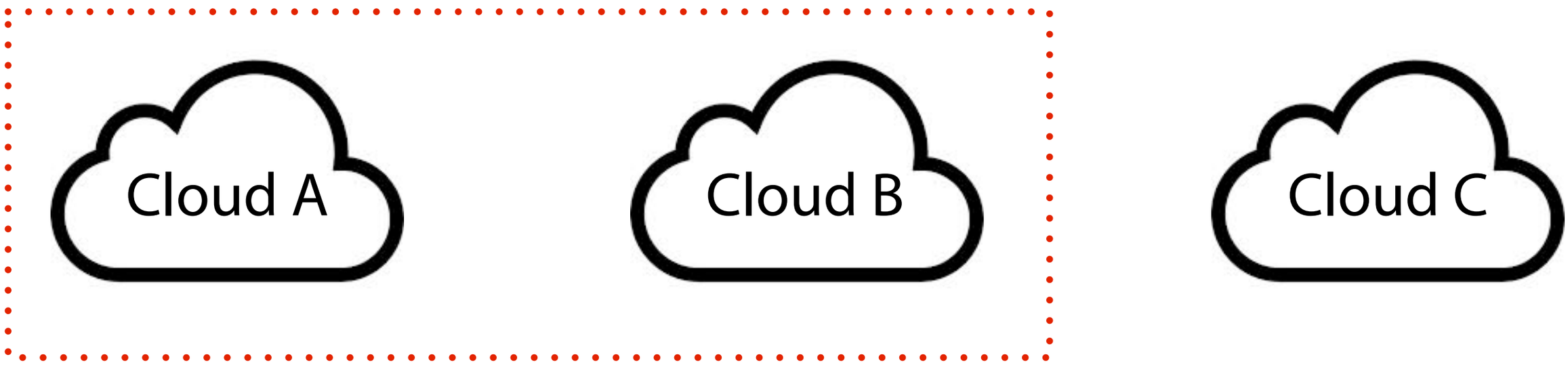
Goal & Insight





Goal & Insight





Goal & Insight

App Provider

B and C ?

Cloud A

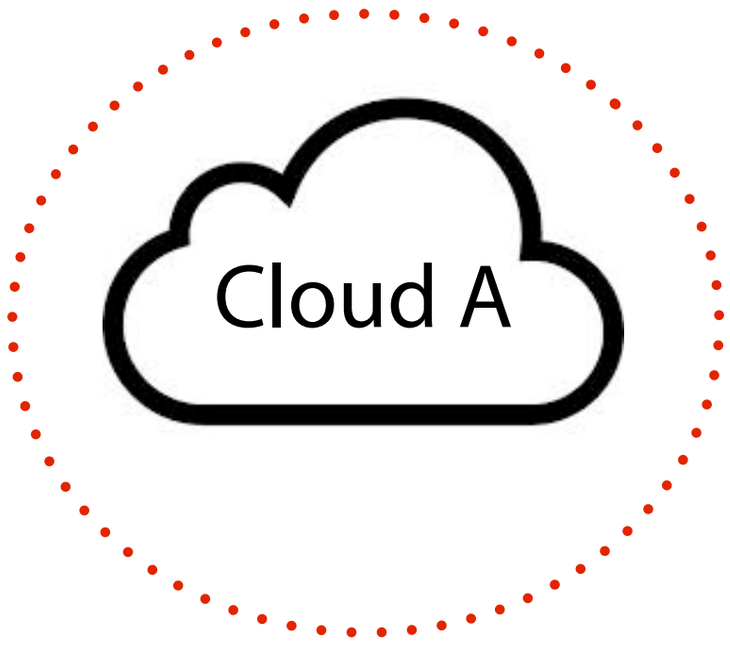
Cloud B

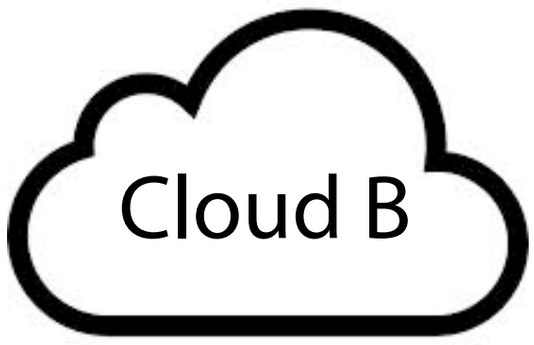
Cloud C

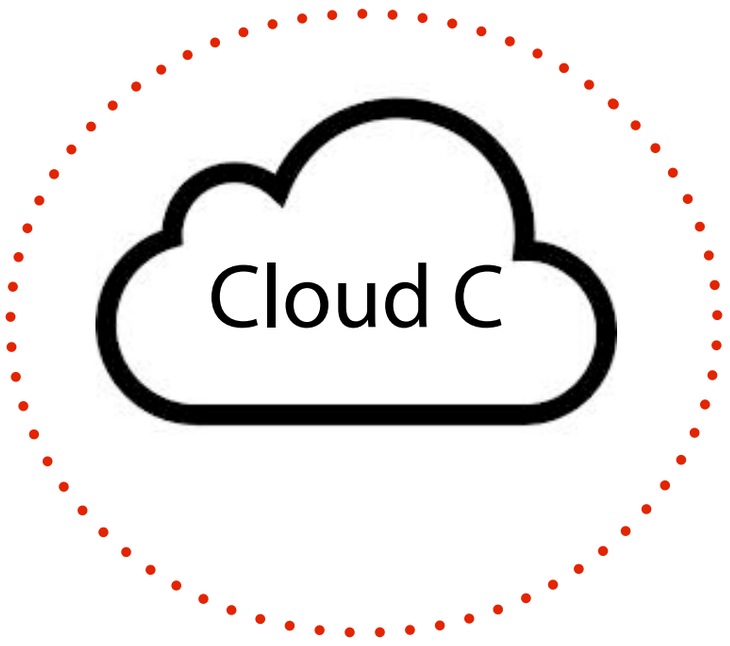
Goal & Insight

App Provider

A and C ?





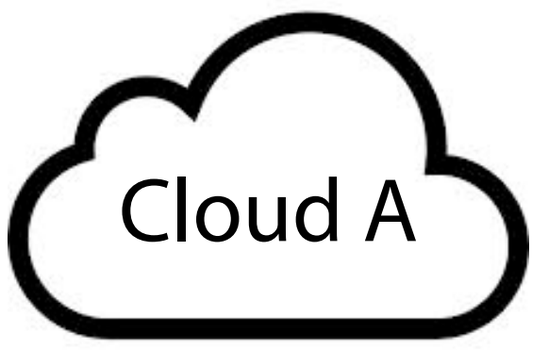


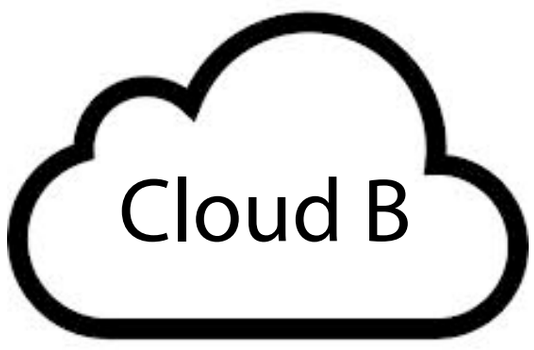
Goal & Insight

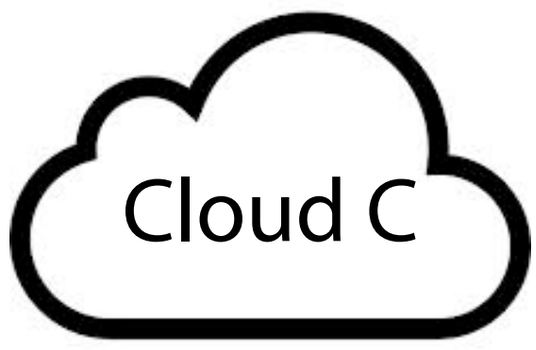
App Provider

Select two clouds for redundancy: A&B? B&C? or A&C?

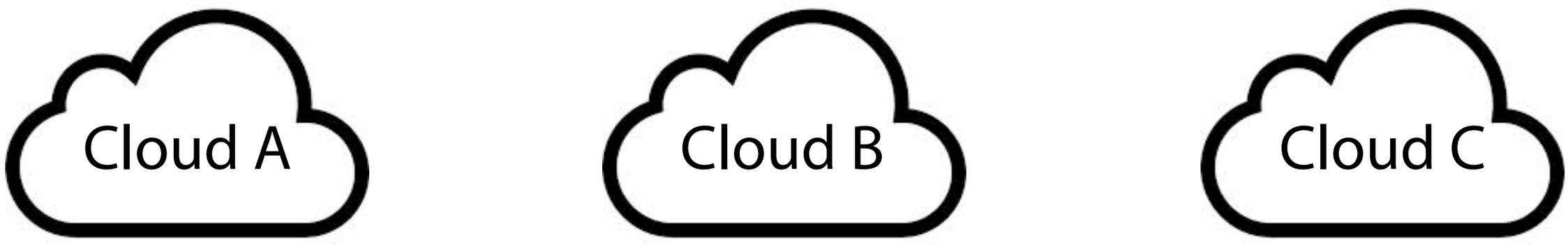
Recommender







Goal & Insight



Goal & Insight

App Provider

Recommender

Assessing independence by the # of overlapping components between clouds

Cloud A

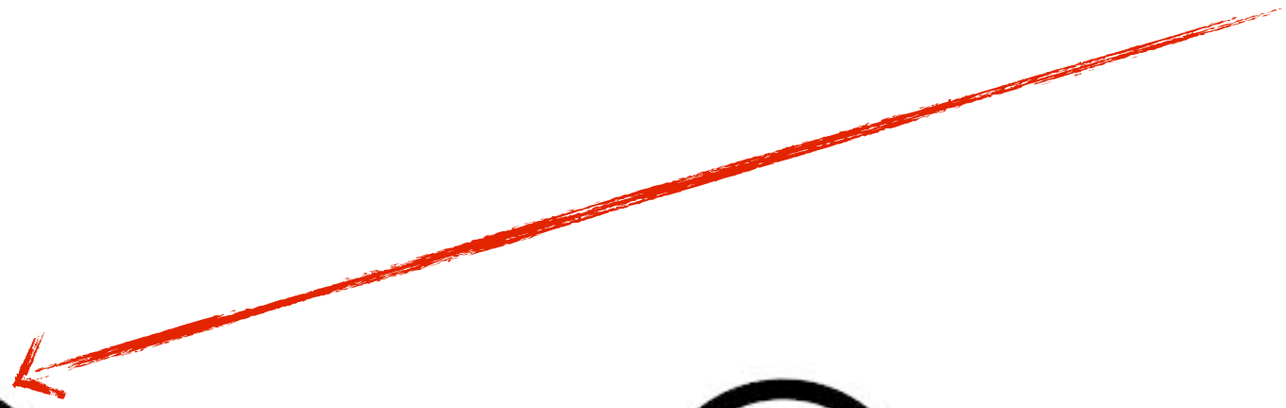
Cloud B

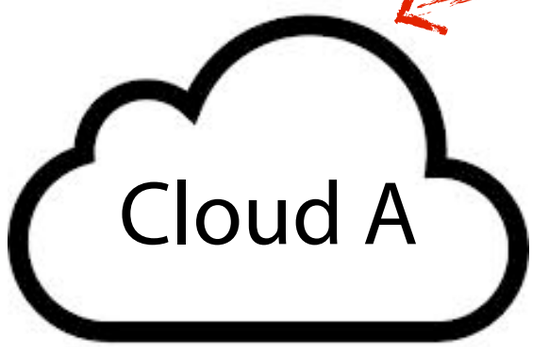
Cloud C

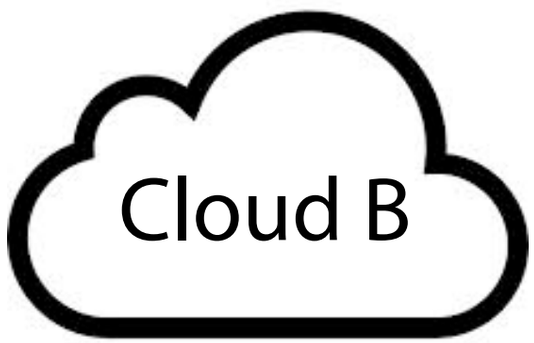
Goal & Insight

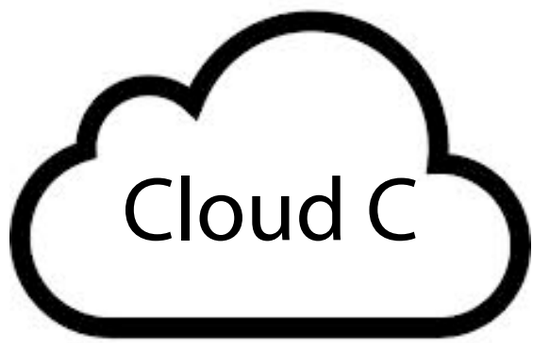
App Provider

Recommender





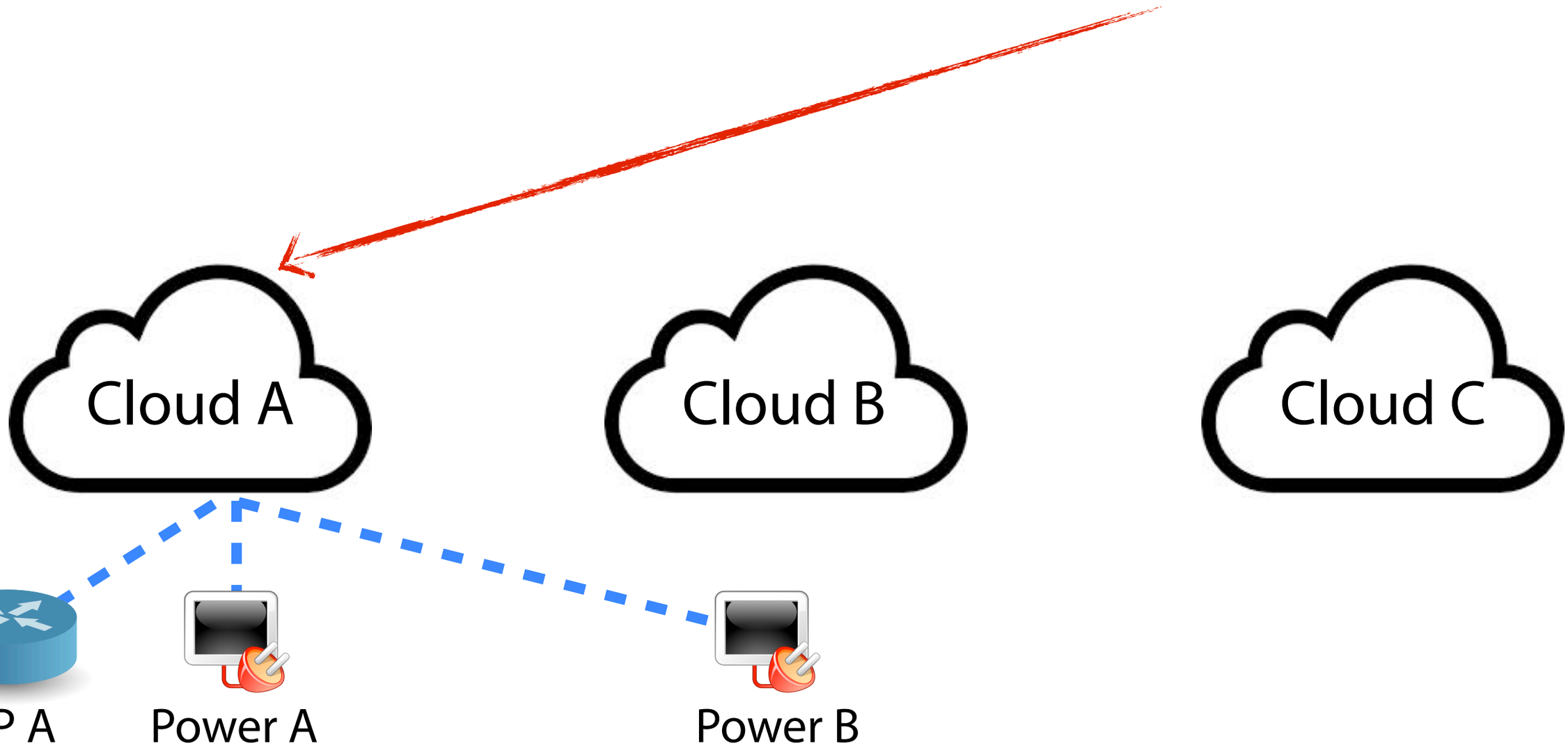




Goal & Insight

App Provider

Recommender



Goal & Insight

App Provider

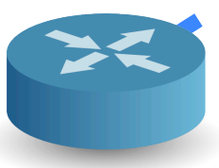
Recommender

ISP A
Power A
Power B

Cloud A

Cloud B

Cloud C



ISP A

Power A

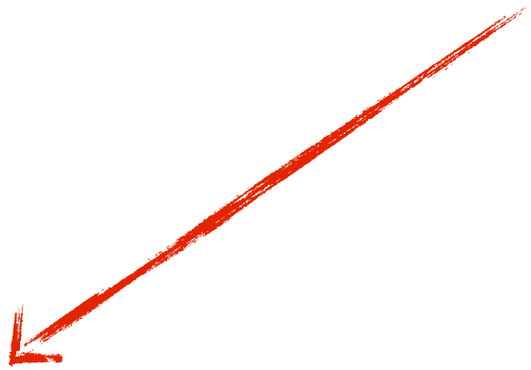
Power B

Goal & Insight

App Provider

Recommender

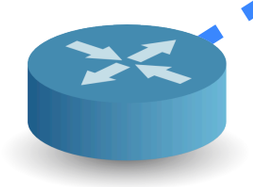
ISP A
Power A
Power B



Cloud A

Cloud B

Cloud C



ISP A

Power A

Power B

Goal & Insight

App Provider

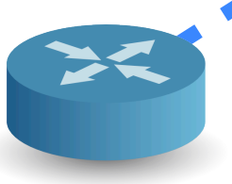
Recommender

ISP A
Power A
Power B

Cloud A

Cloud B

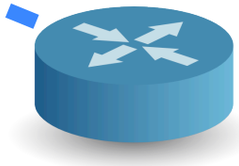
Cloud C



ISP A

Power A

Power B



ISP B

Goal & Insight

App Provider

Recommender

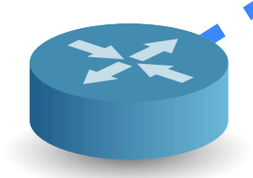
ISP A
Power A
Power B

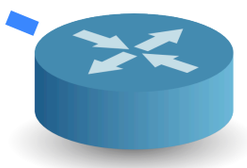
ISP B
Power A
Power B

Cloud A

Cloud B

Cloud C





ISP A

Power A

Power B

ISP B

Goal & Insight

App Provider

Recommender

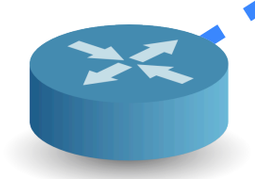
ISP A
Power A
Power B

ISP B
Power A
Power B

Cloud A

Cloud B

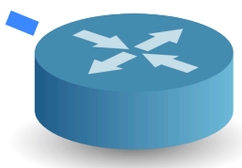
Cloud C



ISP A

Power A

Power B



ISP B

Goal & Insight

App Provider

Recommender

ISP A
Power A
Power B

ISP B
Power A
Power B

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

App Provider

Recommender

ISP A
Power A
Power B

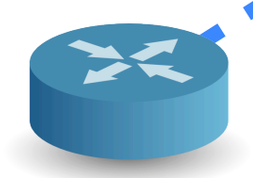
ISP B
Power A
Power B

ISP B
Power C

Cloud A

Cloud B

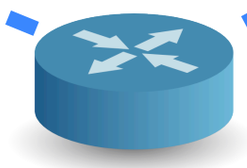
Cloud C



ISP A

Power A

Power B



ISP B

Power C

Goal & Insight

Deployment	∩

App Provider

Recommender

ISP A
Power A
Power B

ISP B
Power A
Power B

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

Deployment	∩

App Provider

Recommender

ISP A
Power A
Power B

ISP B
Power A
Power B

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

Deployment	∩

App Provider

Recommender

ISP A
Power A
Power B

∩
=2

ISP B
Power A
Power B

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

Deployment	|∩|
Cloud A, B	2

App Provider

Recommender

ISP A
Power A
Power B

∩
=2

ISP B
Power A
Power B

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

Deployment	|∩|
Cloud A, B	2

App Provider

Recommender

ISP A
Power A
Power B

ISP B
Power A
Power B

∩

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

Deployment	|∩|
Cloud A, B	2

App Provider

Recommender

ISP A
Power A
Power B

ISP B
Power A
Power B

∩

=1

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

App Provider

Recommender

Deployment	|∩|
Cloud B, C	1
Cloud A, B	2

ISP A
Power A
Power B

ISP B
Power A
Power B

∩

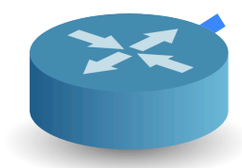
=1

ISP B
Power C

Cloud A

Cloud B

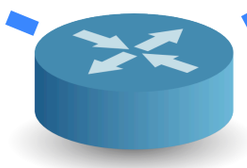
Cloud C



ISP A

Power A

Power B



ISP B

Power C

Goal & Insight

Deployment	|∩|
Cloud B, C	1
Cloud A, B	2

App Provider

Recommender

ISP A
Power A
Power B

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

Deployment	|∩|
Cloud B, C	1
Cloud A, B	2

App Provider

Recommender

ISP A
Power A
Power B

∩ =0

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Goal & Insight

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

App Provider

Recommender

ISP A
Power A
Power B

∩ =0

ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

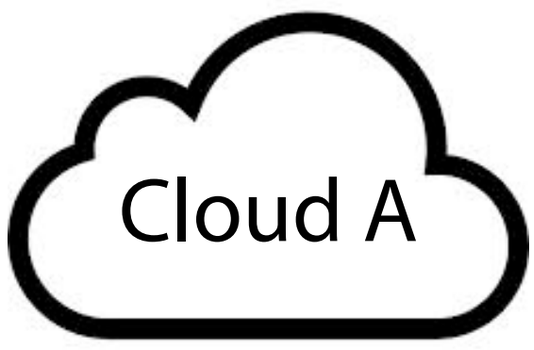
Power C

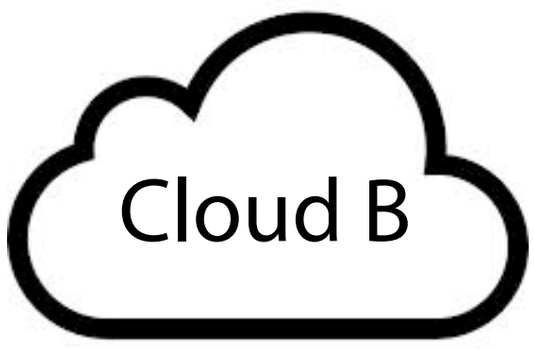
Goal & Insight

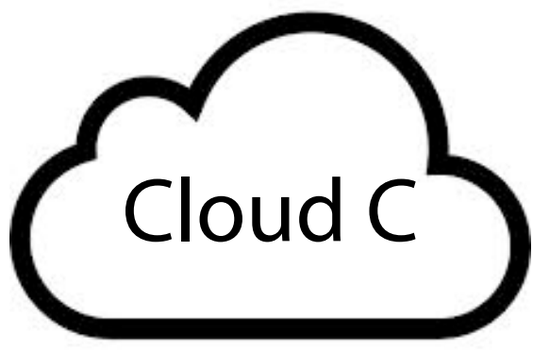
App Provider

Recommender

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2







Goal & Insight

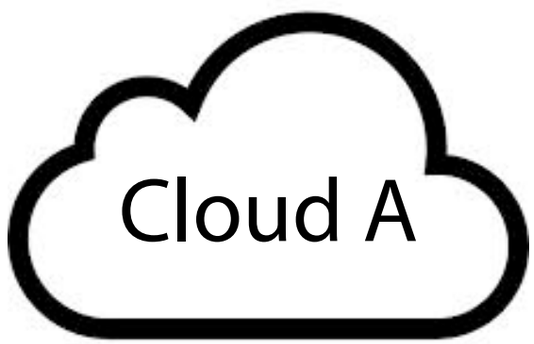
App Provider

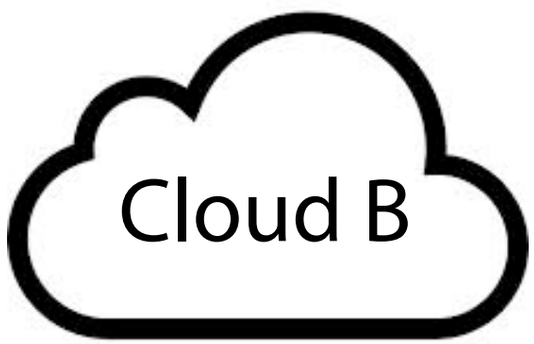
Ranking List

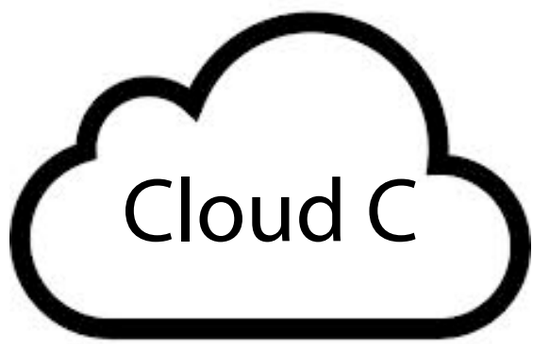
Deployment	|∩|
1. Cloud A, C	0
2. Cloud B, C	1
3. Cloud A, B	2

Recommender

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2







Road-Map

- Motivations
- Goal & Insight
- iRec System
- Next Steps

Road-Map

- Motivations
- Goal & Insight
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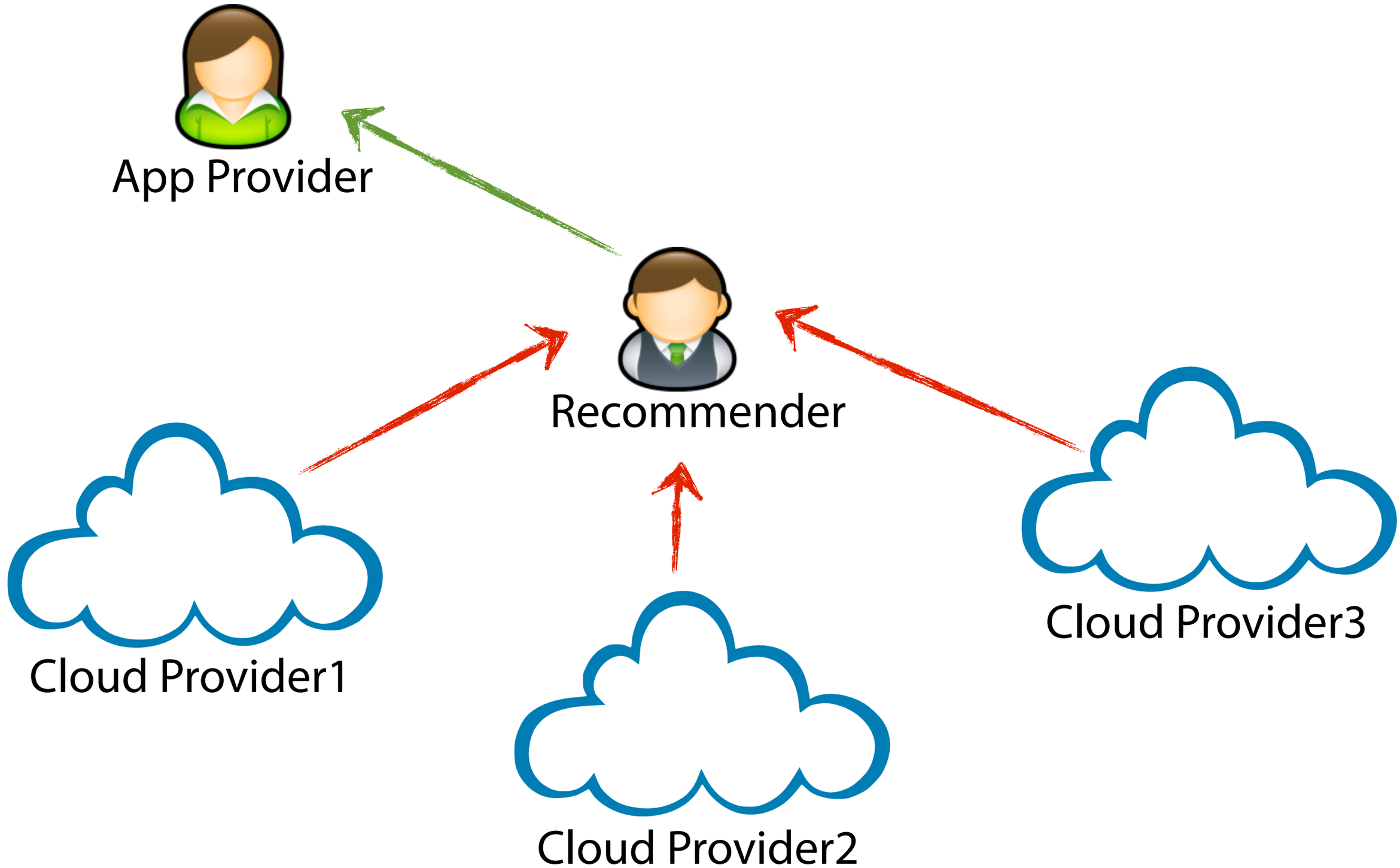
- Next Steps

Strawman Solution 1



Strawman Solution 1

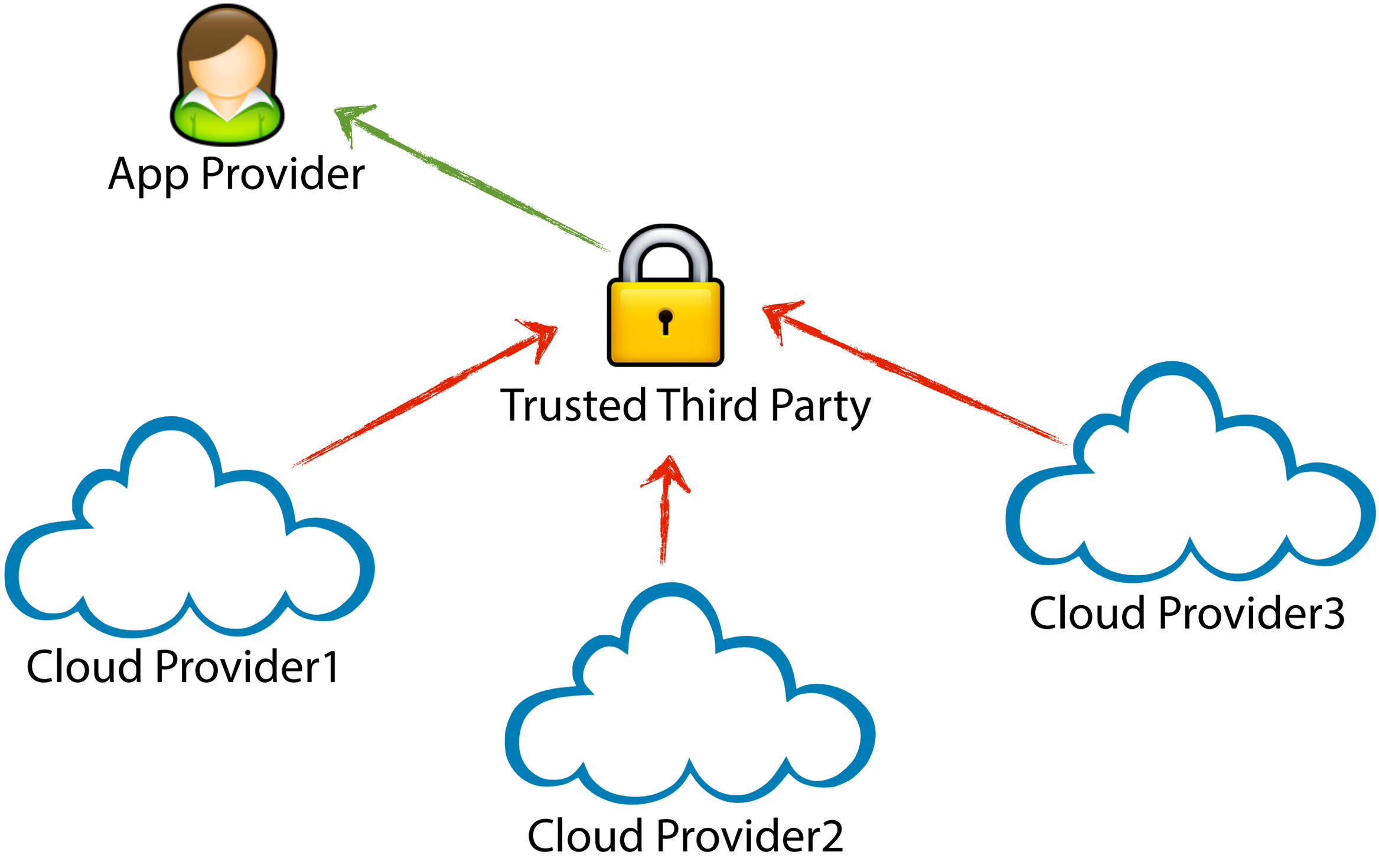
Privacy Concern!

Cloud Provider1

Cloud Provider2

Cloud Provider3

Strawman Solution 2



Strawman Solution 2

It is hard to find!

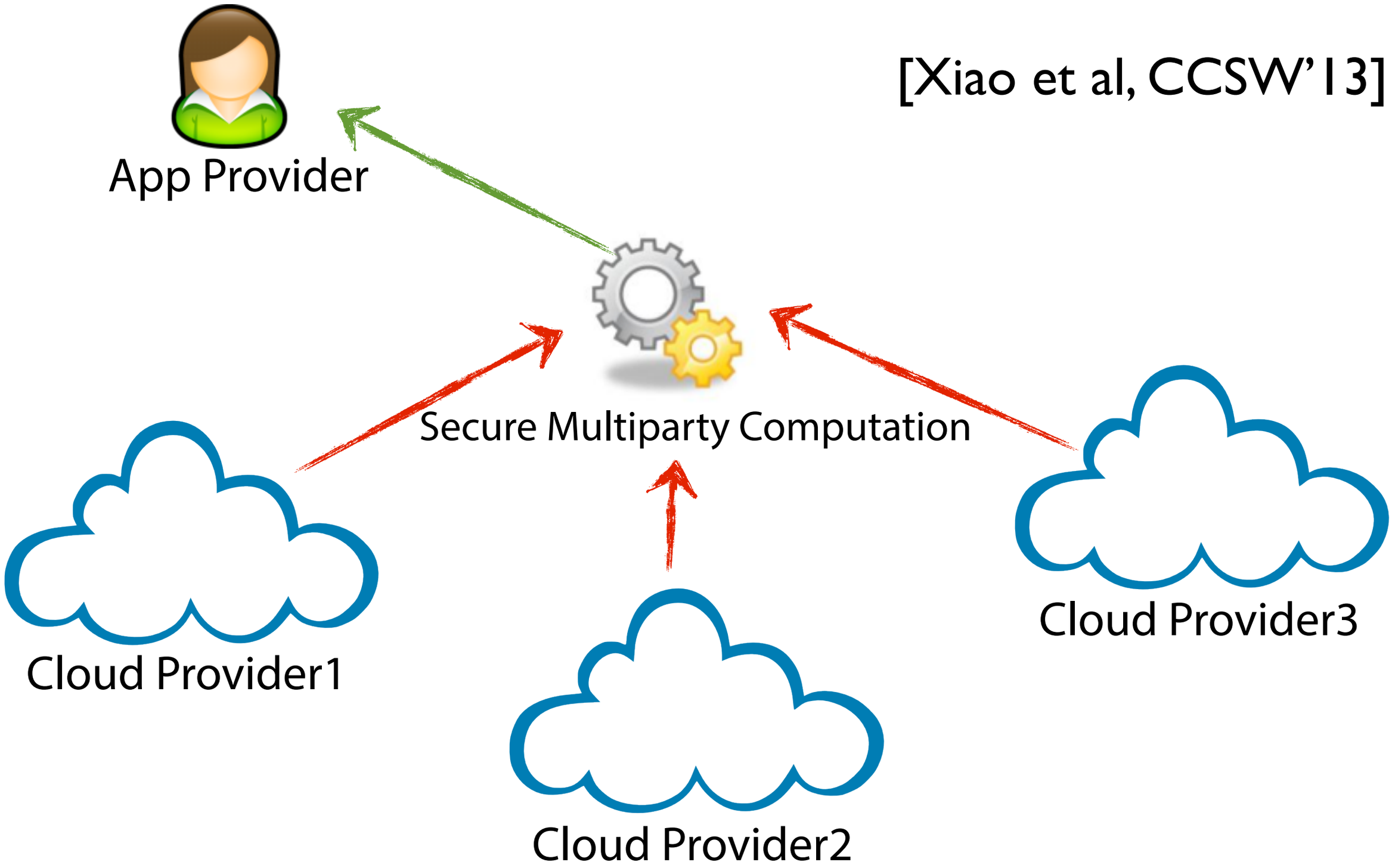
Cloud Provider1

Cloud Provider2

Cloud Provider3

Strawman Solution 3

[Xiao et al, CCSW'13]



Strawman Solution 3

[Xiao et al, CCSW'13]

SMPC is difficult to scale!

Cloud Provider1

Cloud Provider2

Cloud Provider3

Our Approach - iRec

- The first cloud independence recommender sys:
  - achieving our goal
  - preserving privacy of each cloud provider
  - practical

Our Approach - iRec

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Preliminary background: PSI-CA

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- Allows *k* parties to compute the # of overlapping elements without learning other information.

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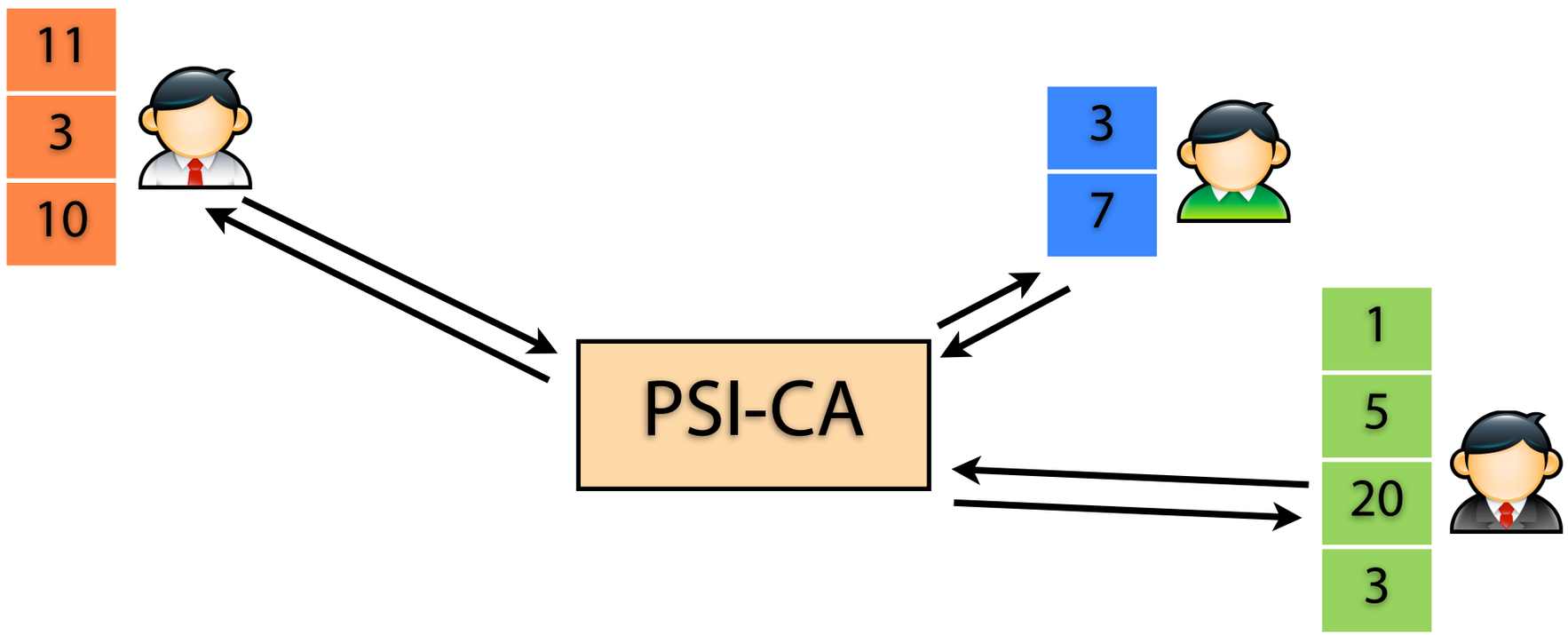

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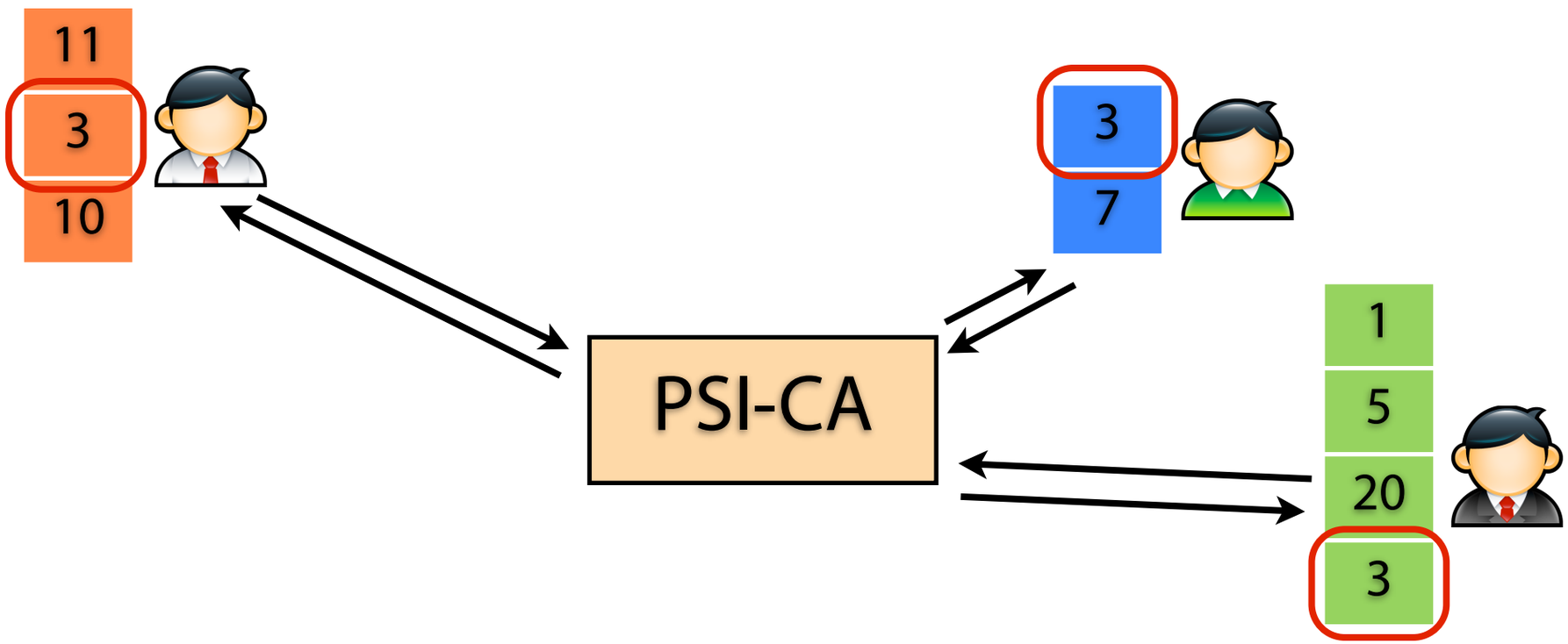

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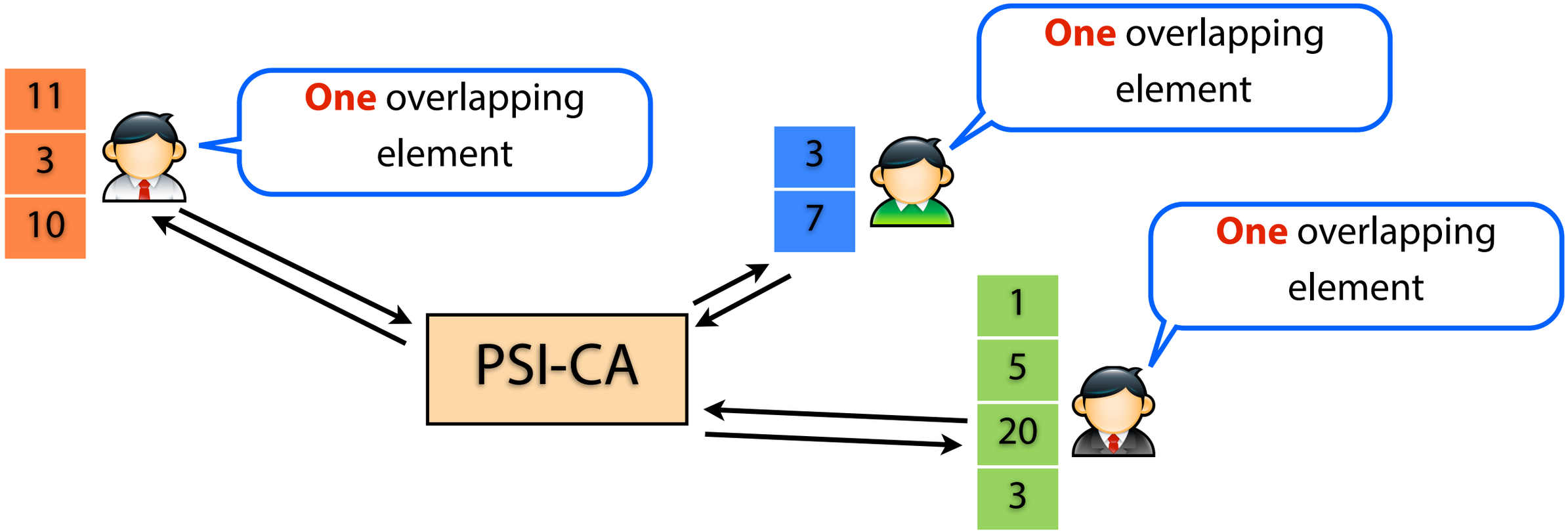

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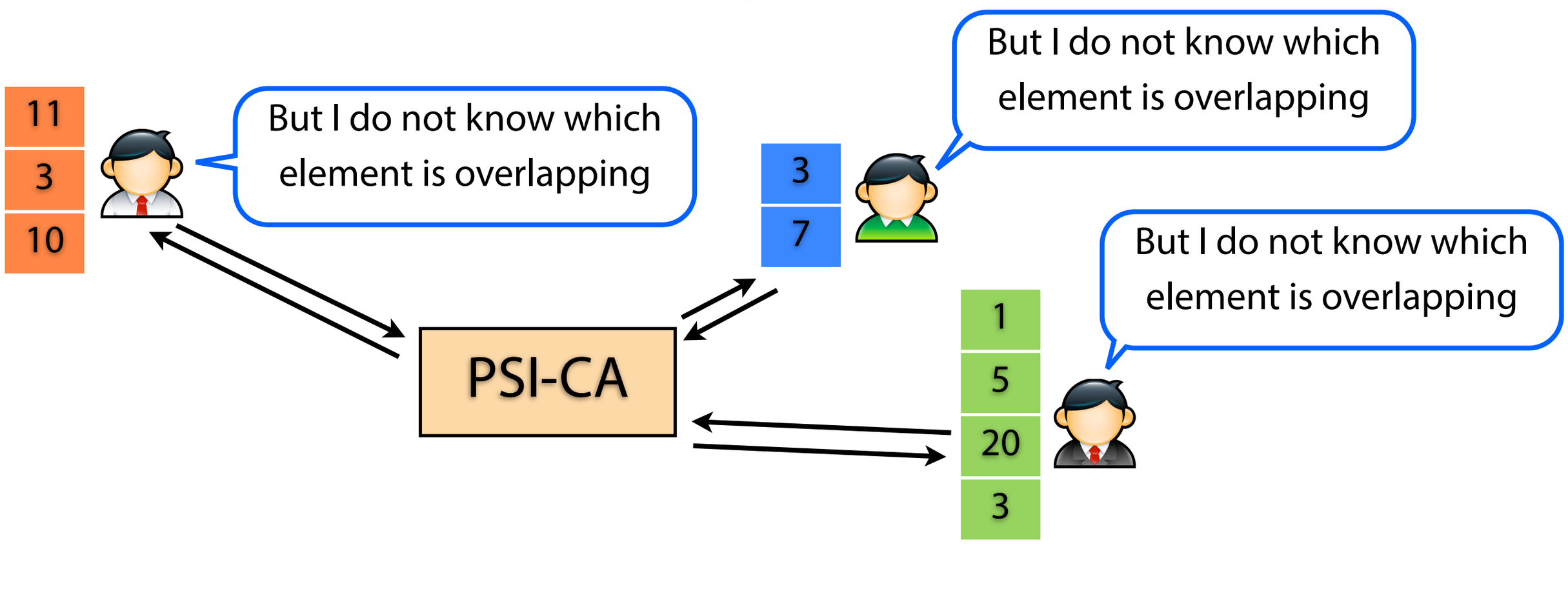

Preliminary: PSI-CA

12

5

4

Data Set A

1

4

6

2

Data Set B

• Alice and Bob has set A and B respectively and Alice wants to jointly compute $|A \cap B|$.

Preliminary: PSI-CA

Alice

$P = (X-12)(X-5)(X-4)$
$= x^3-21x^2+128X-240$

12

5

4

Data Set A

Bob

1

4

6

2

Data Set B

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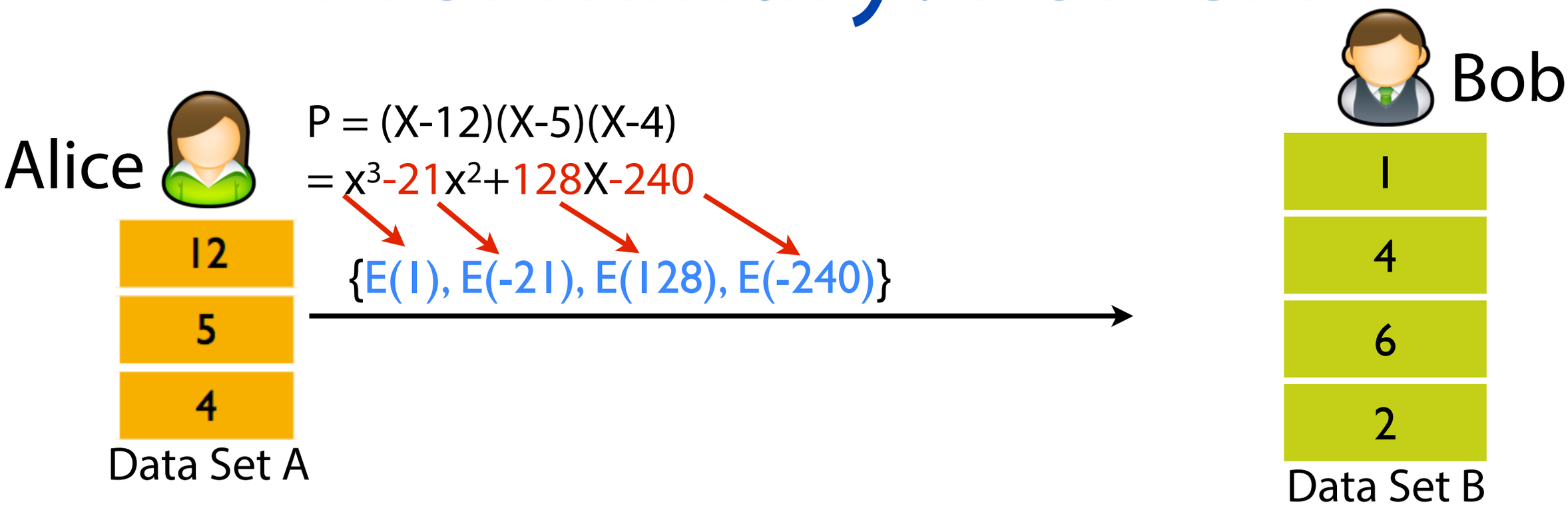
- Alice makes a polynomial P whose roots are the elements of data set A.

Preliminary: PSI-CA



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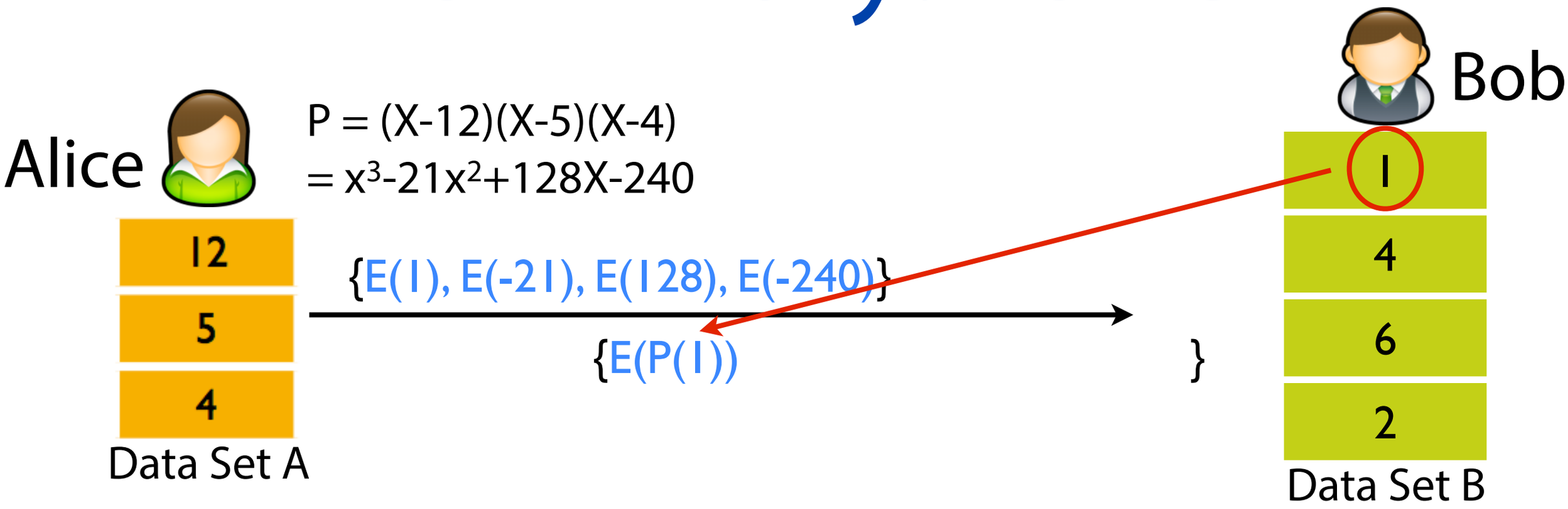
• Alice encrypts the coefficients of P and sends them to Bob. Note that Alice sends homomorphic encryptions of the coefficients to Bob.

Preliminary: PSI-CA



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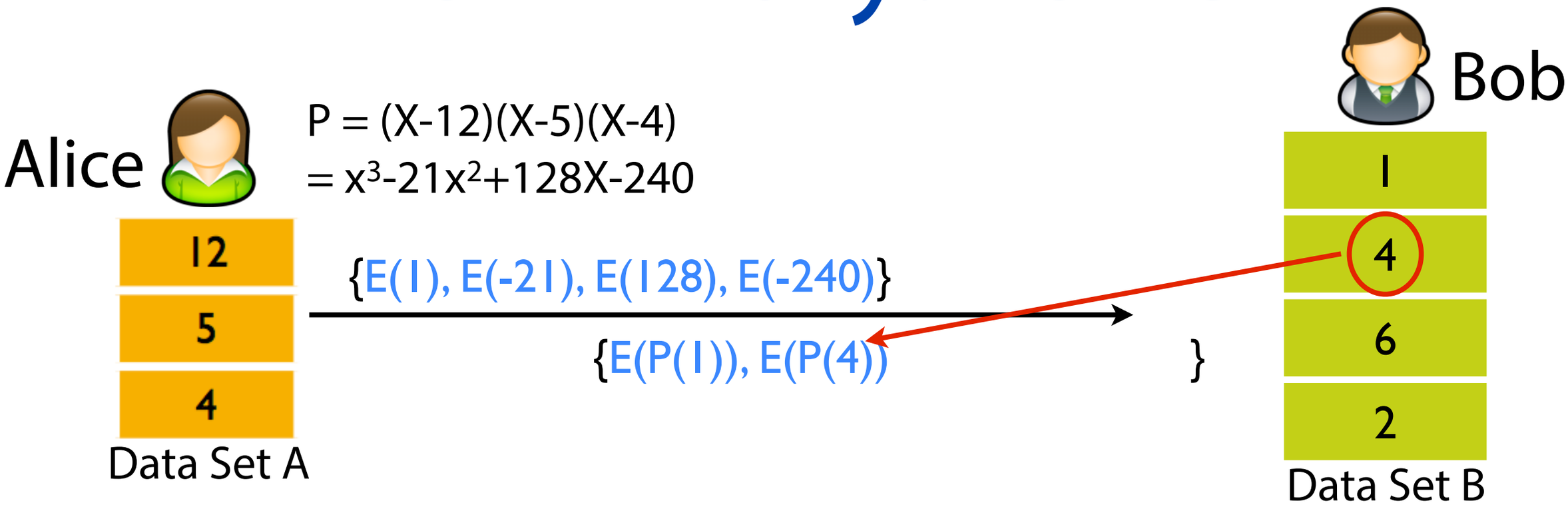

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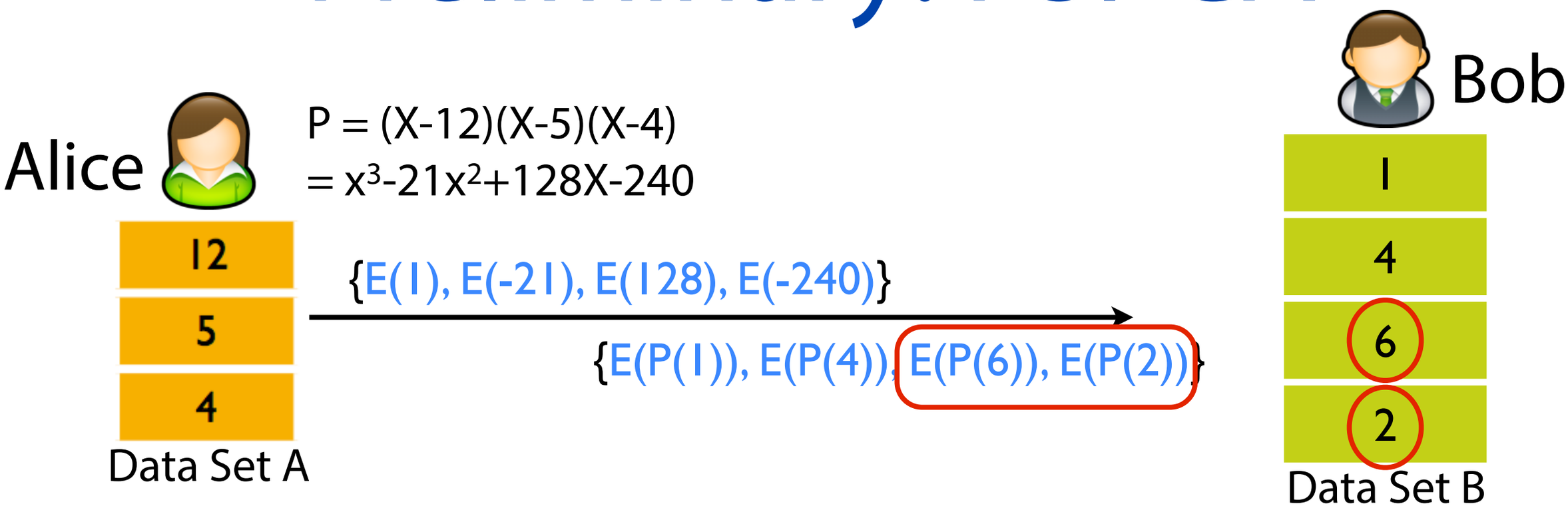

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Preliminary: PSI-CA

$P = (X-12)(X-5)(X-4)$
$= x^3-21x^2+128X-240$

12
5
4

Data Set A

{E(1), E(-21), E(128), E(-240)}

{E(-132), E(0), E(-12), E(-60)}

1
4
6
2

Data Set B

- Alice and Bob has set A and B respectively and Alice wants to jointly compute $|A \cap B|$.
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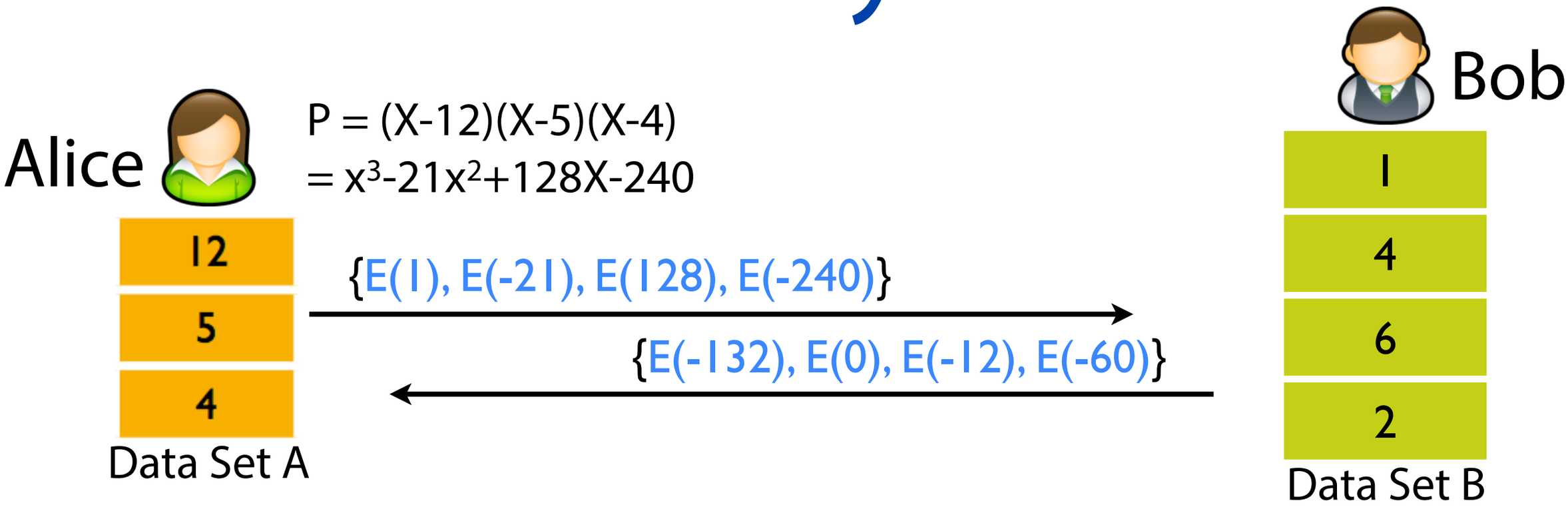
Preliminary: PSI-CA



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- Bob returns the encrypted evaluations to Alice.

Preliminary: PSI-CA

Alice 

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$= x^3-21x^2+128X-240$

12

5

4

Data Set A

$\{-132, 0, -12, -60\}$

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- Alice decrypts it and counts the number of zeroes.

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{-132, 0, -12, -60}

12
5
4
Data Set A

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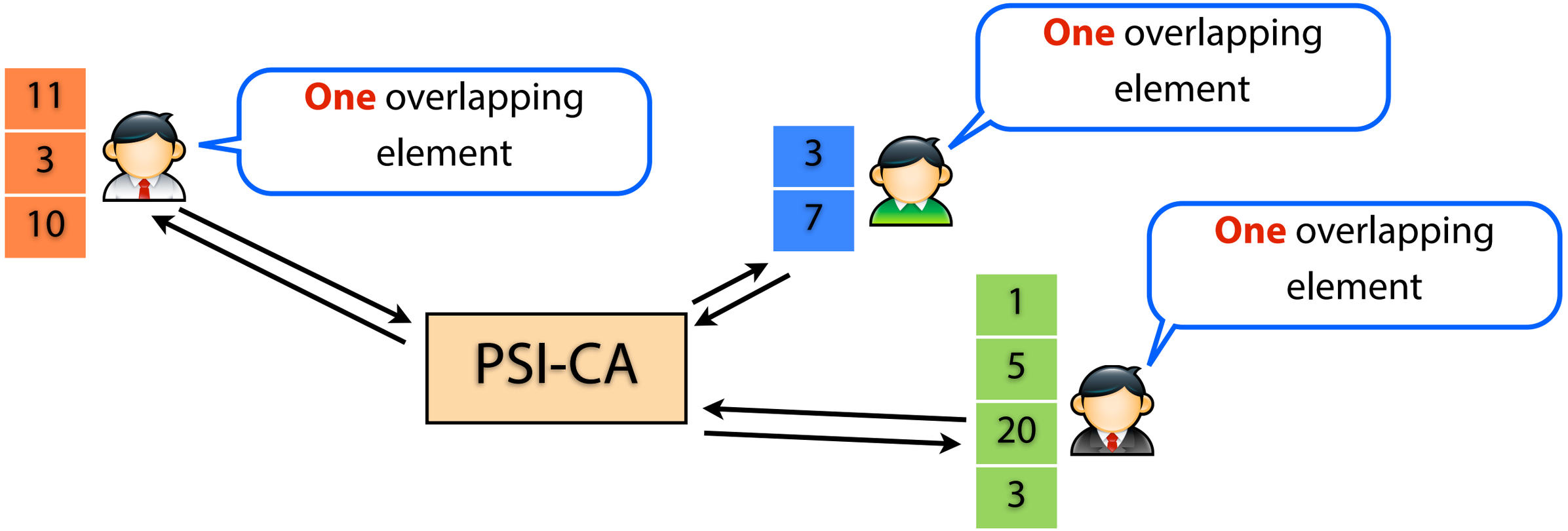
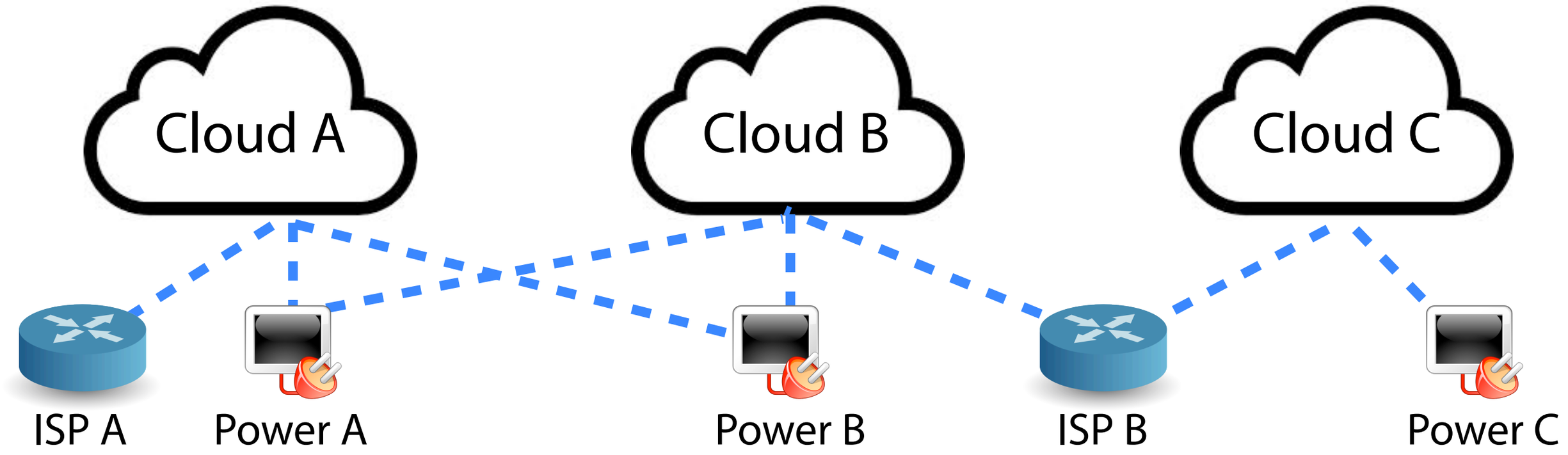
Preliminary: PSI-CA



Our Approach - iRec

App Provider

iRec



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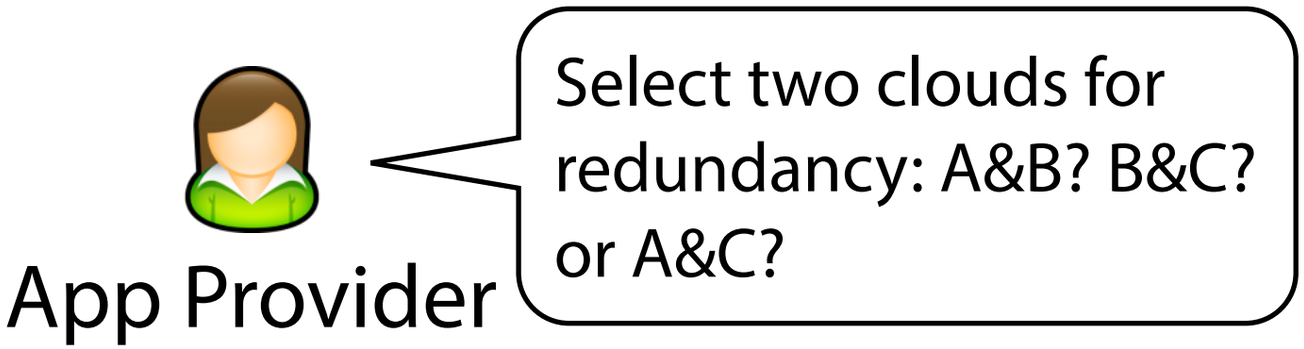
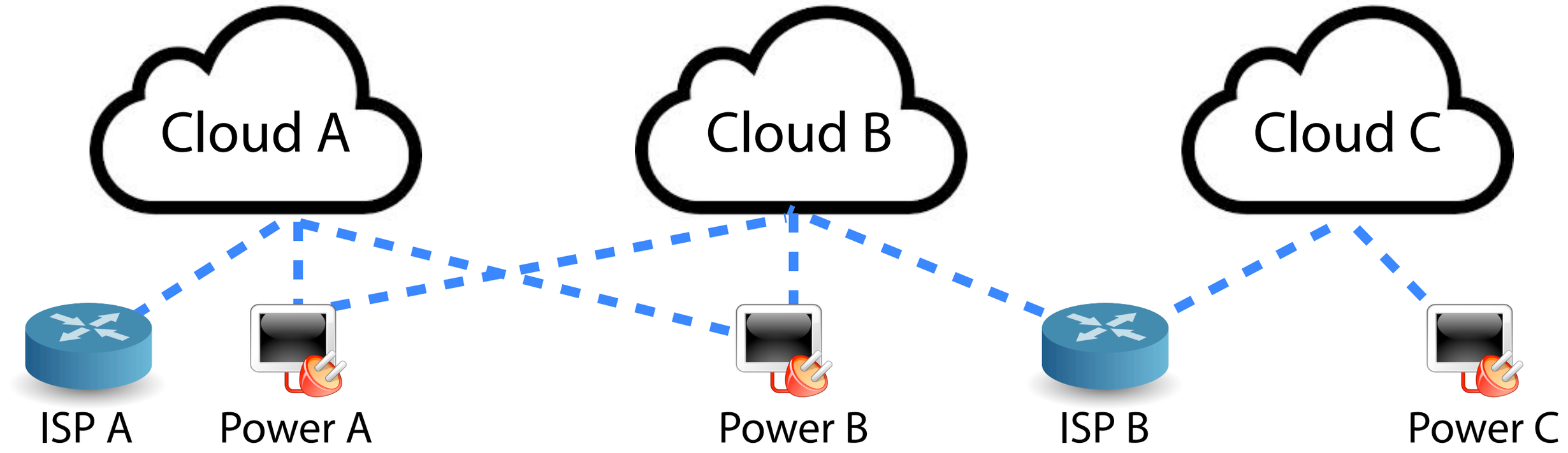
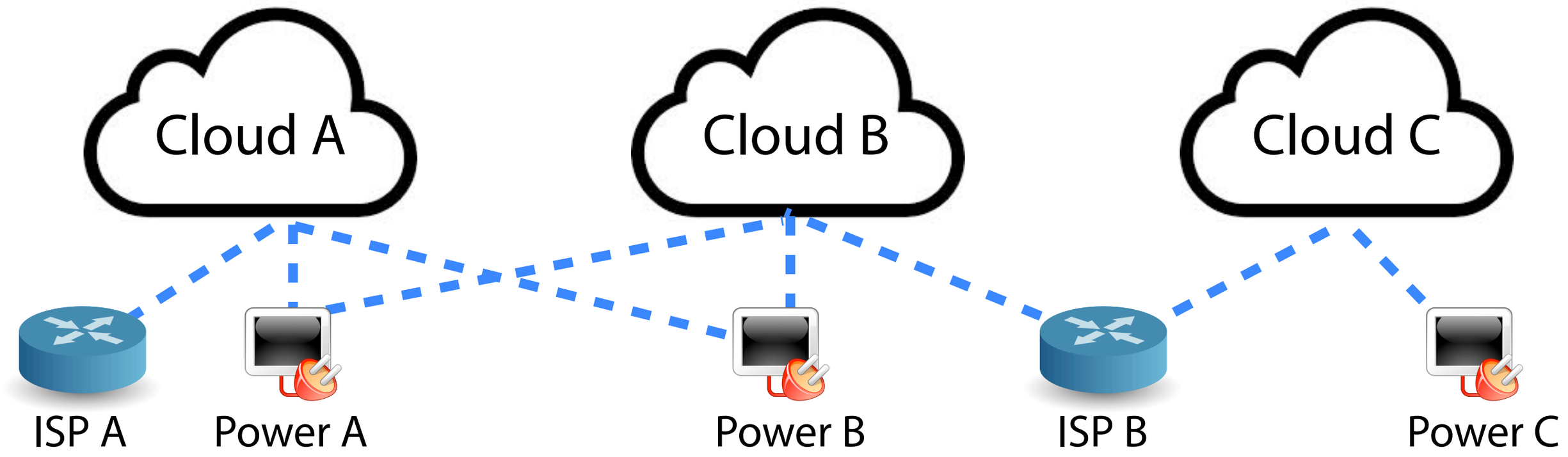


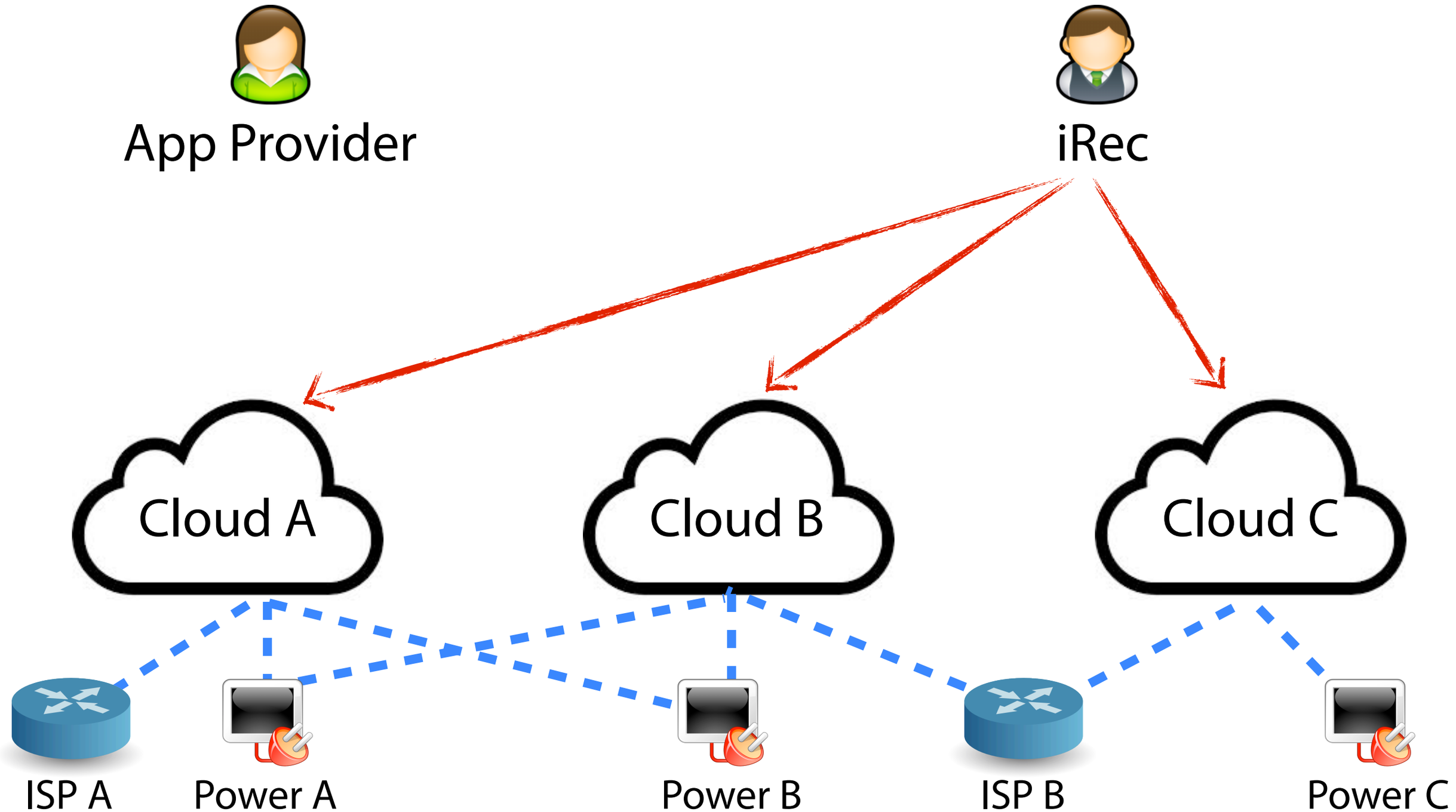


Step 1


App Provider
iRec


Cloud A
Cloud B
Cloud C
ISP A
Power A
Power B
ISP B
Power C

Step 2


App Provider
iRec
Cloud A
Cloud B
Cloud C
ISP A
Power A
Power B
ISP B
Power C

Step 3

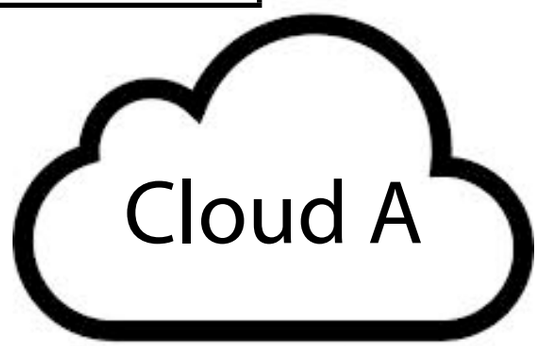
App Provider

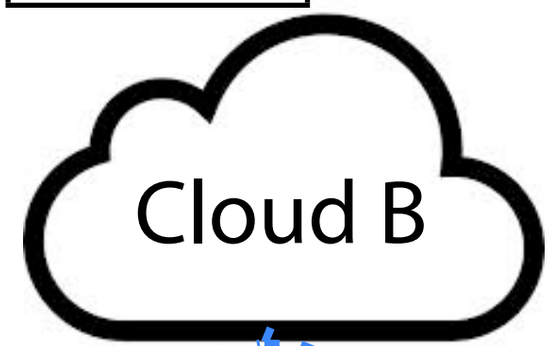
iRec

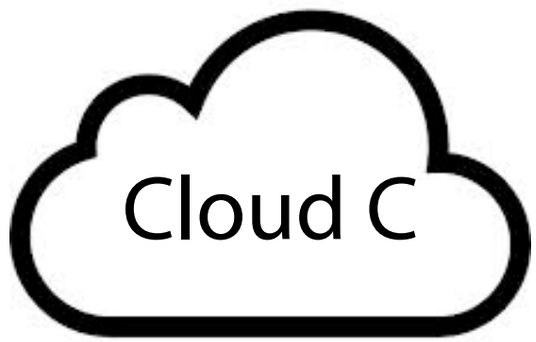
ISP A
Power A
Power B

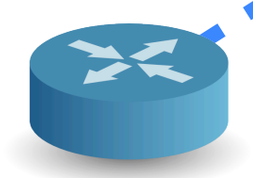
ISP B
Power A
Power B

ISP B
Power C









ISP A

Power A

Power B

ISP B

Power C

Step 3

App Provider

iRec

ISP A
Power A
Power B

PSI-CA

ISP B
Power A
Power B

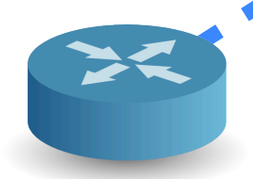
PSI-CA

ISP B
Power C

Cloud A

Cloud B

Cloud C



ISP A

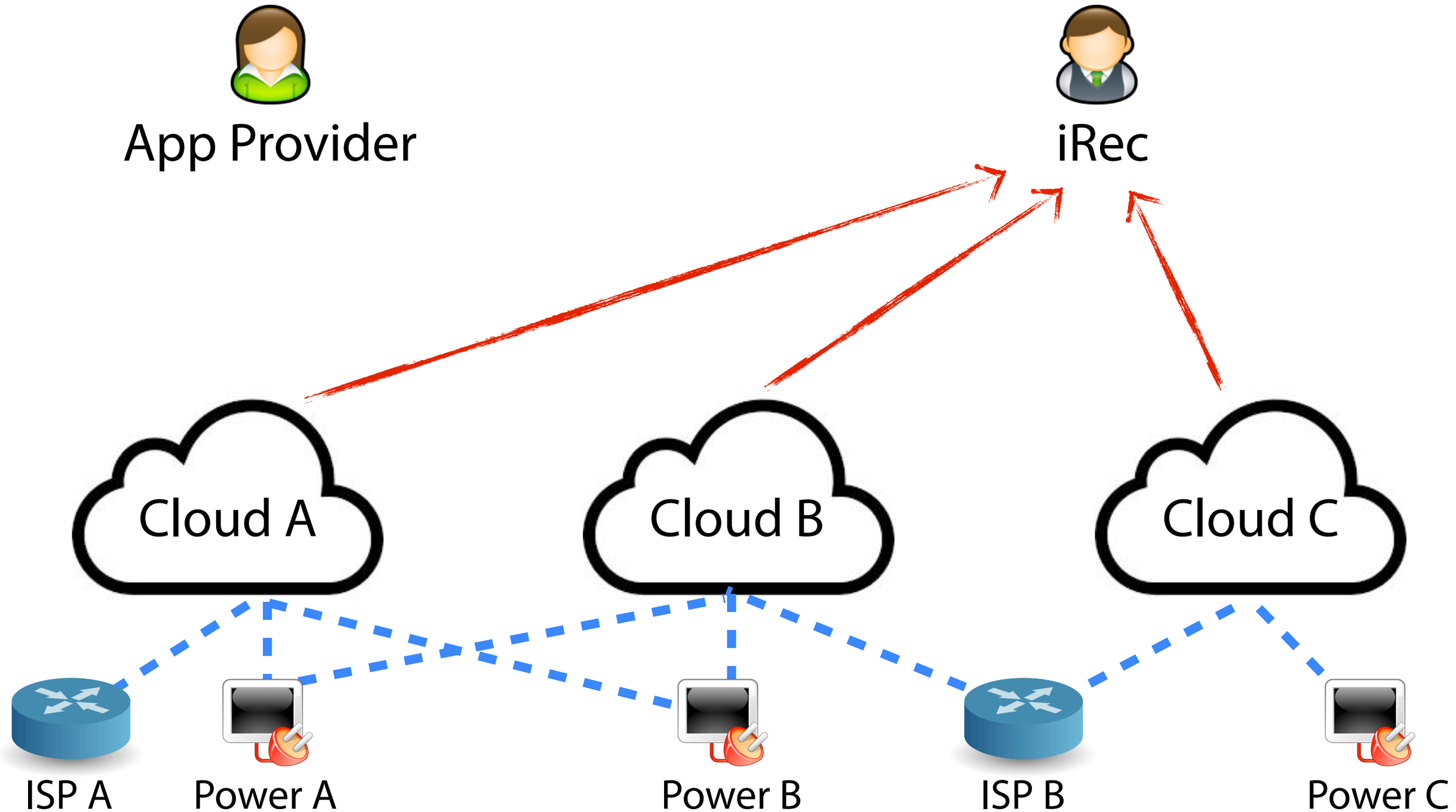
Power A

Power B

ISP B

Power C

Step 4

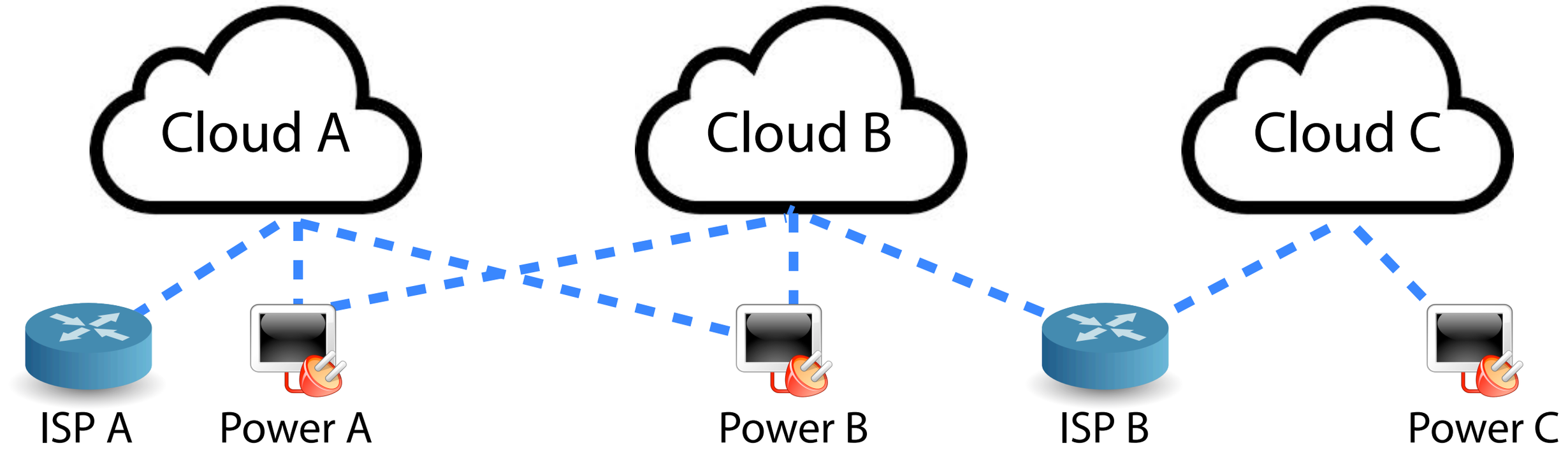

App Provider
iRec
Cloud A
Cloud B
Cloud C
ISP A
Power A
Power B
ISP B
Power C

Step 5

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

App Provider

Recommender



Step 5

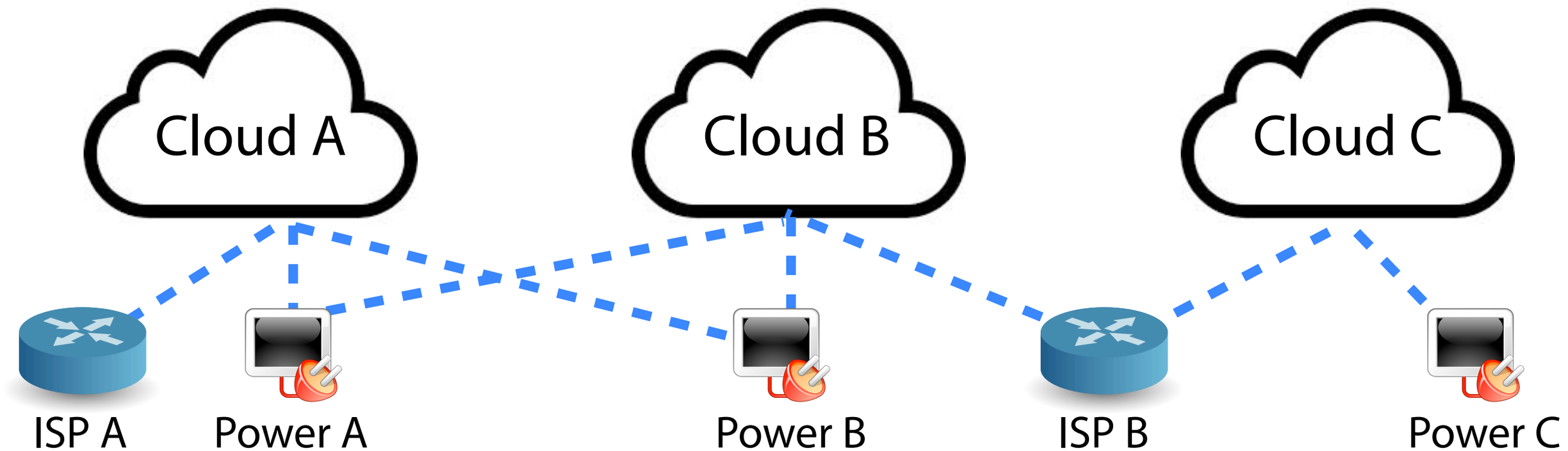
Deployment	∩
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

Ranking List

App Provider

Deployment	∩
1. Cloud A, C	0
2. Cloud B, C	1
3. Cloud A, B	2

Recommender



An Improvement Version

- Different infrastructure components play different roles in the clouds

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- Different infrastructure components play different roles in the clouds
- Power source might be much more likely to fail than ISPs

An Improvement Version

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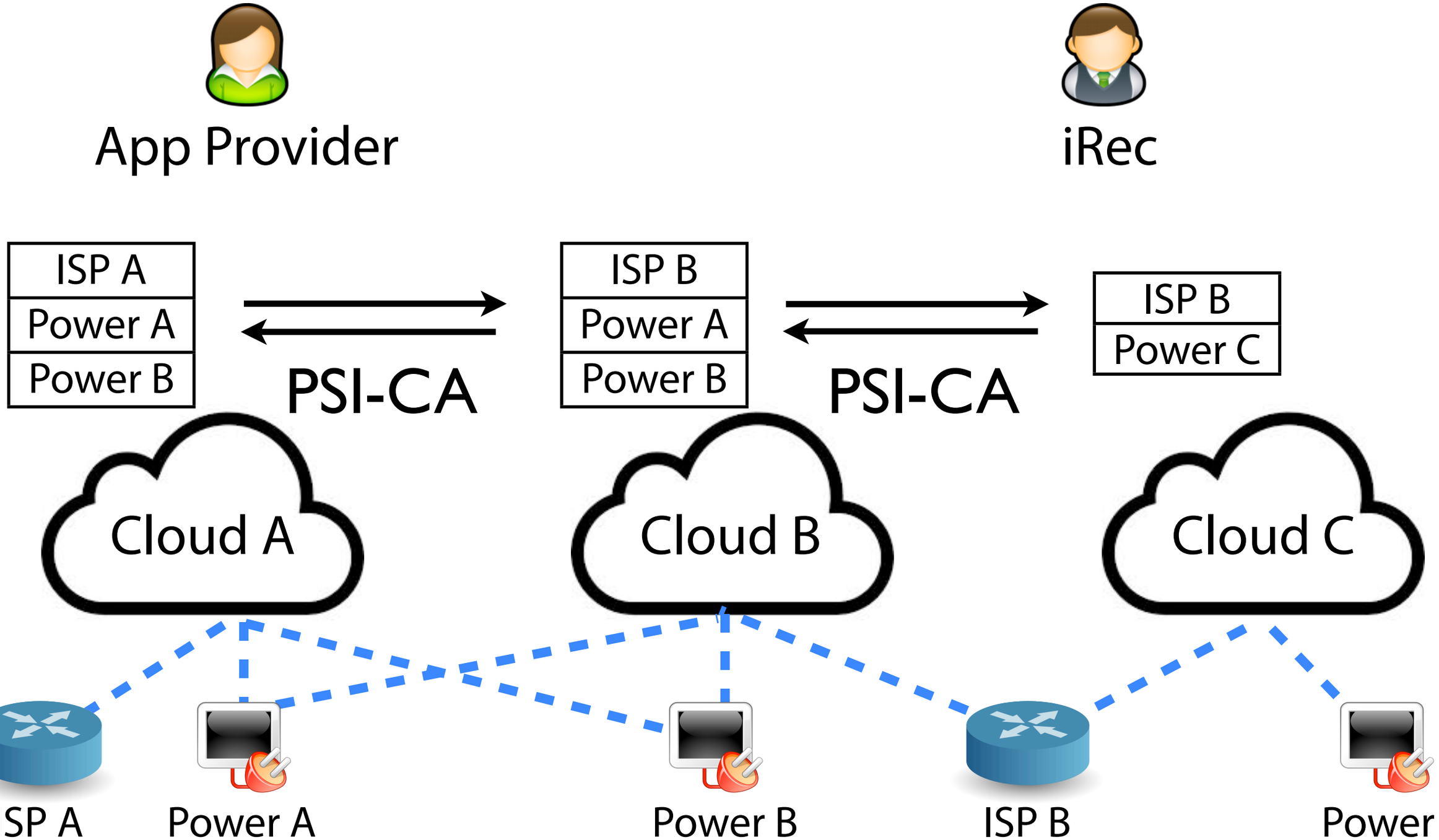
- We propose an improvement version

An Improvement Version

- Different infrastructure components play different roles in the clouds
- Power source might be much more likely to fail than ISPs

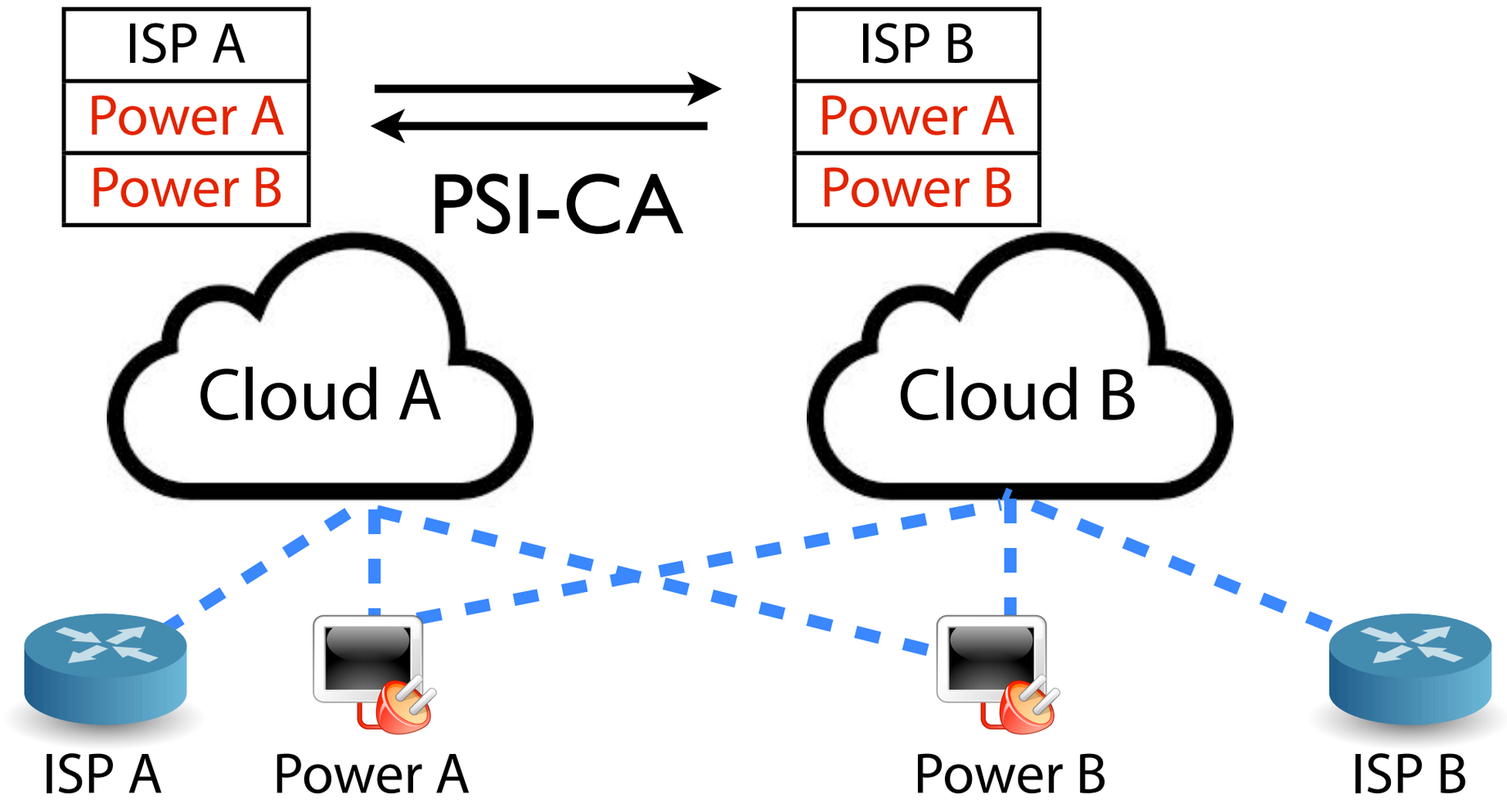
- We propose an improvement version
  - Using Weighted PSI-CA (W-PSI-CA) to instead of PSI-CA in Step3
  - No other improvement

Recall: Step 3

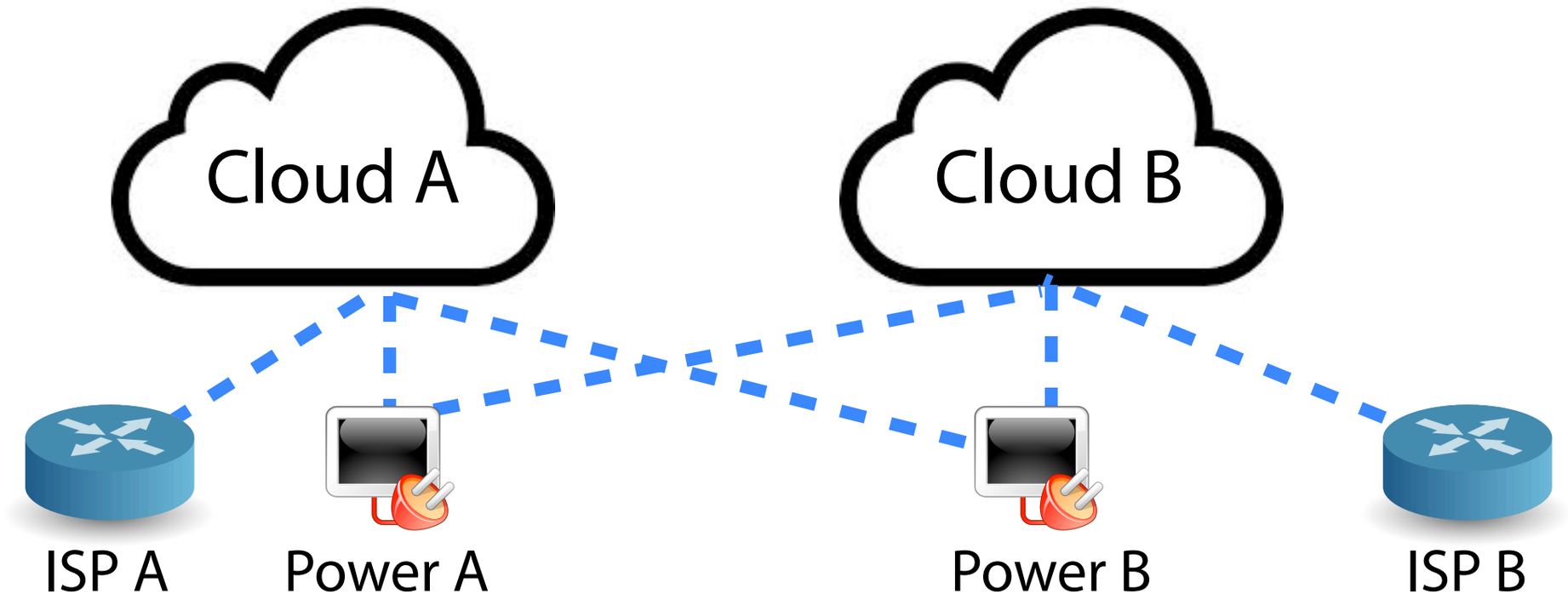


Recall: Step 3

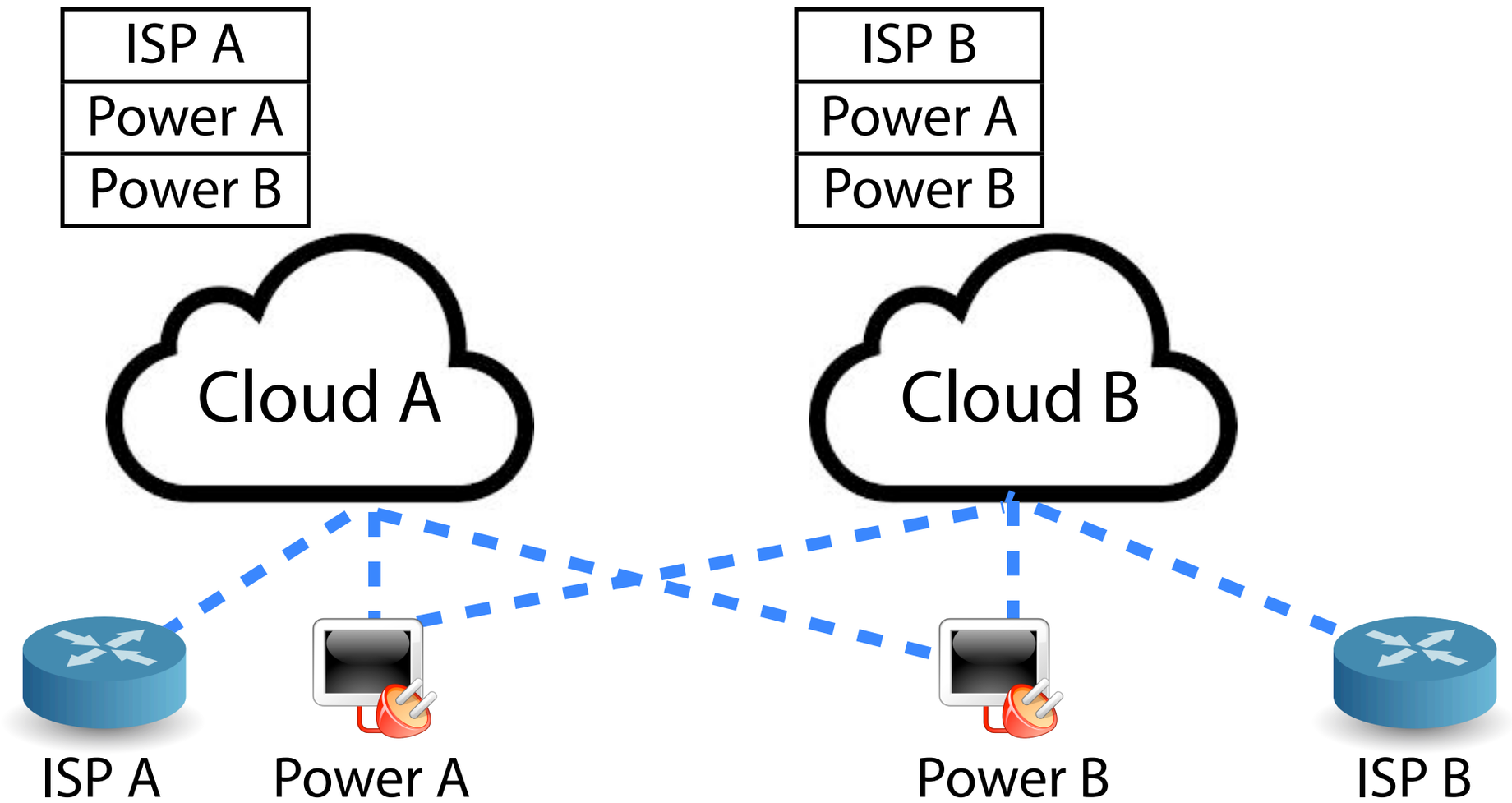
Result is 2



Using W-PSI-CA



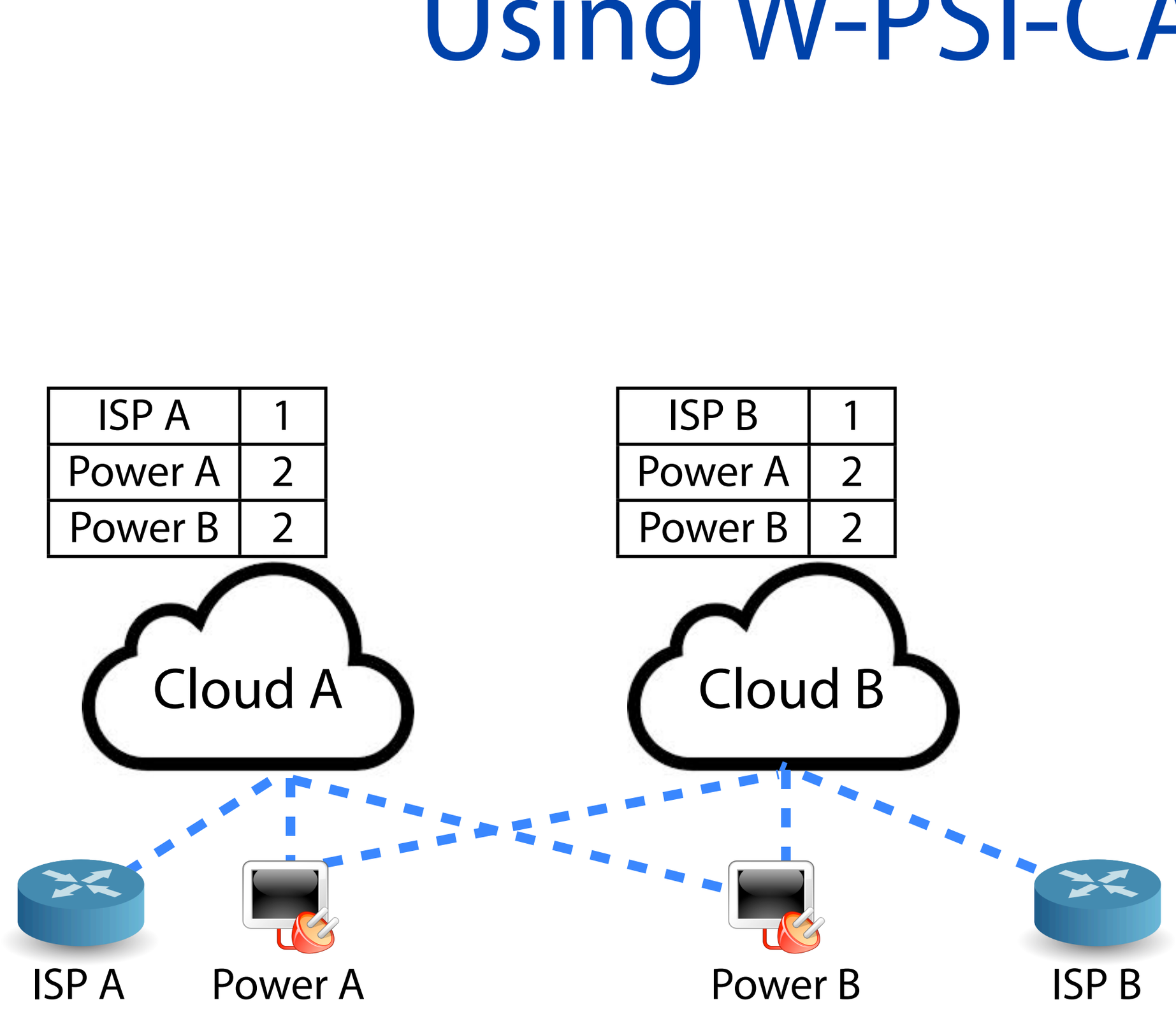
Using W-PSI-CA



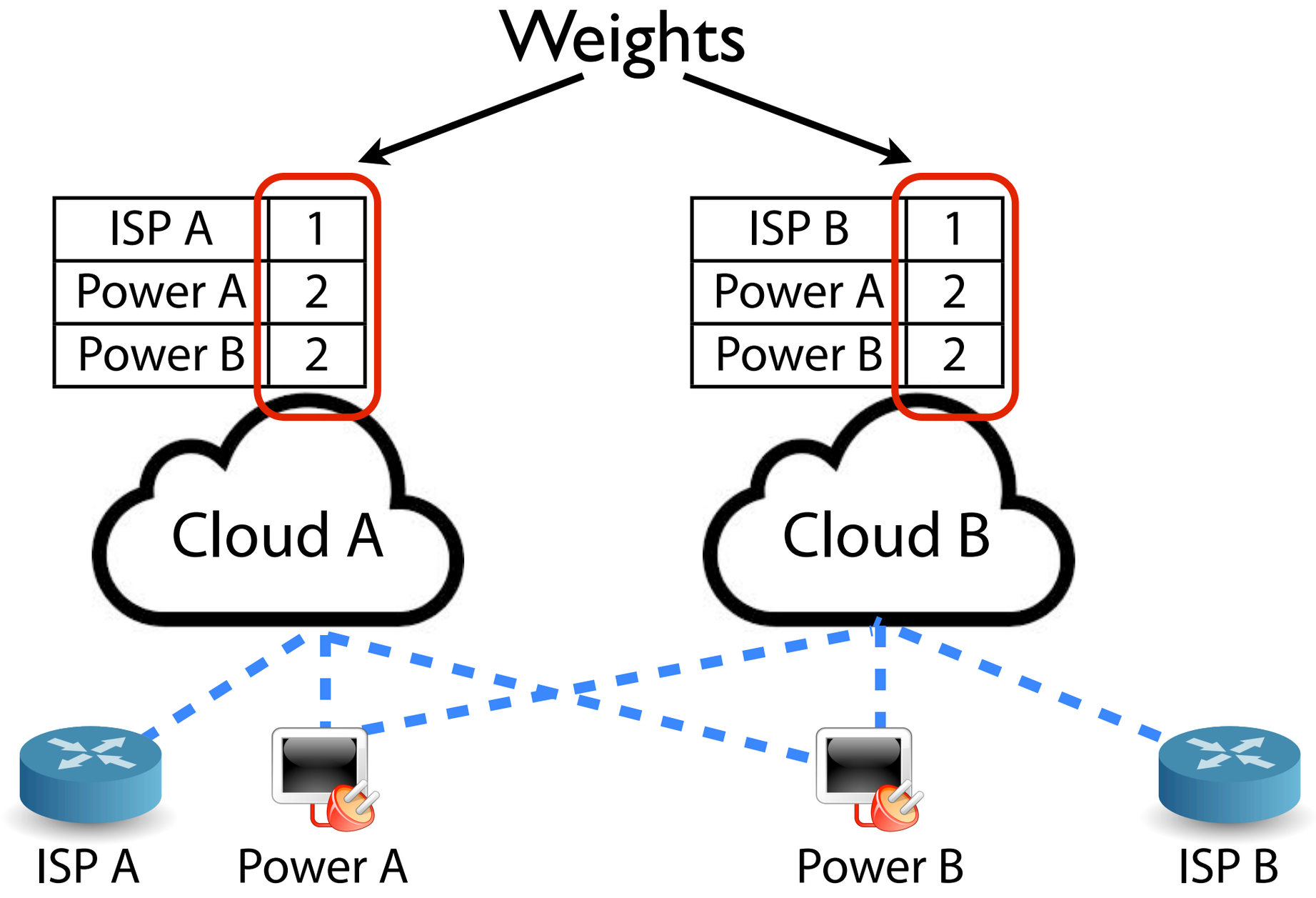
Using W-PSI-CA

ISP A	1
Power A	2
Power B	2

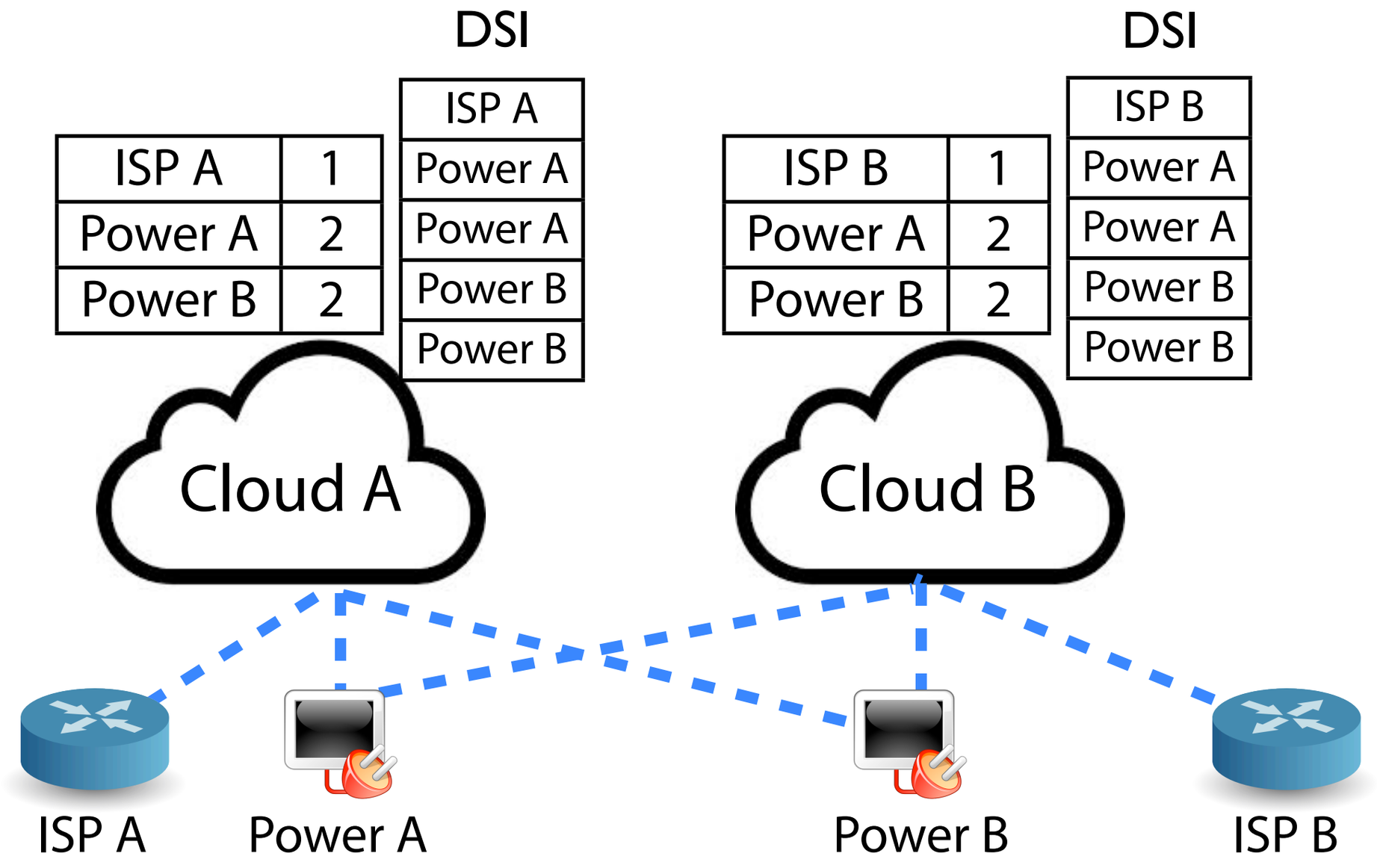
ISP B	1
Power A	2
Power B	2



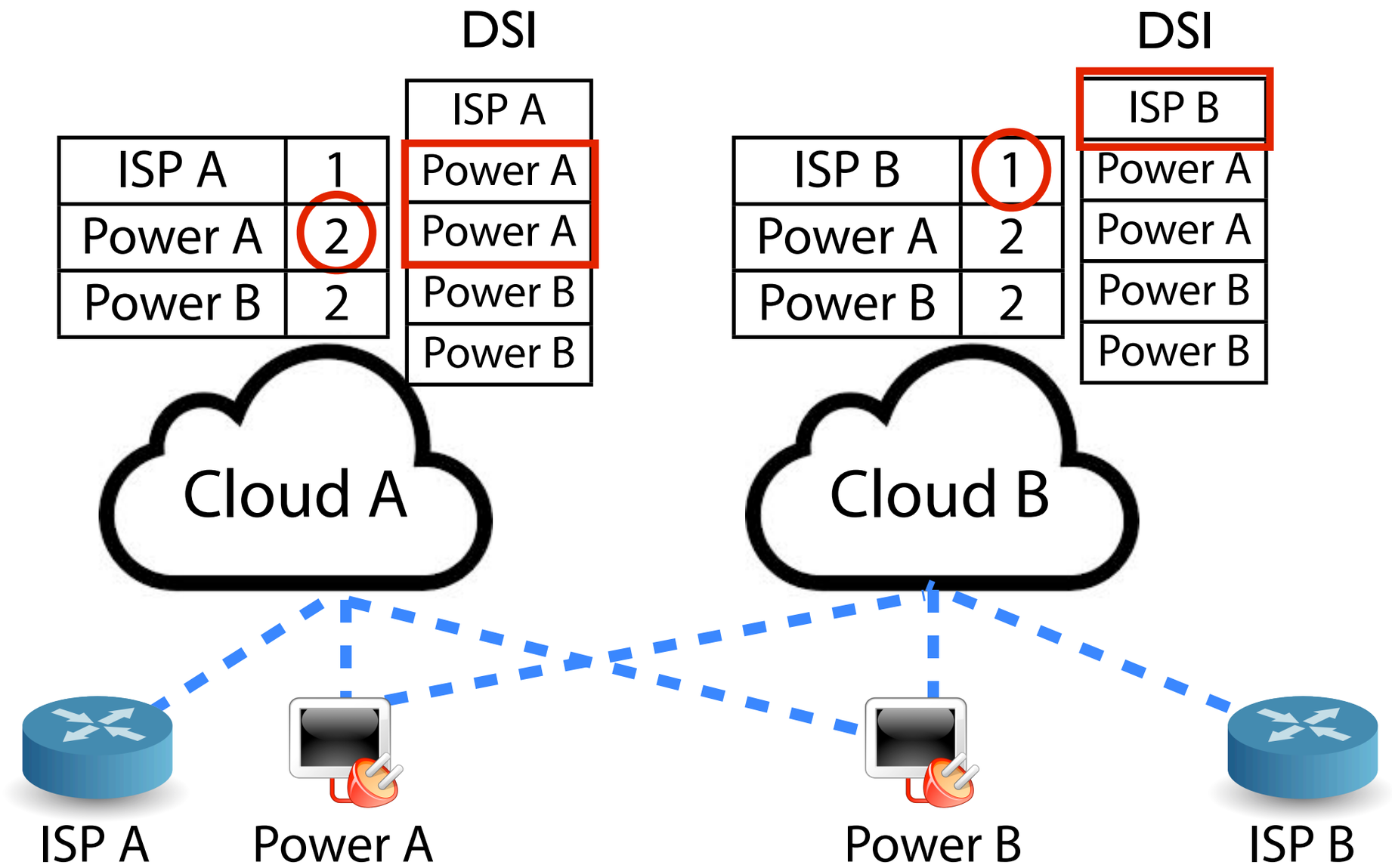
Using W-PSI-CA



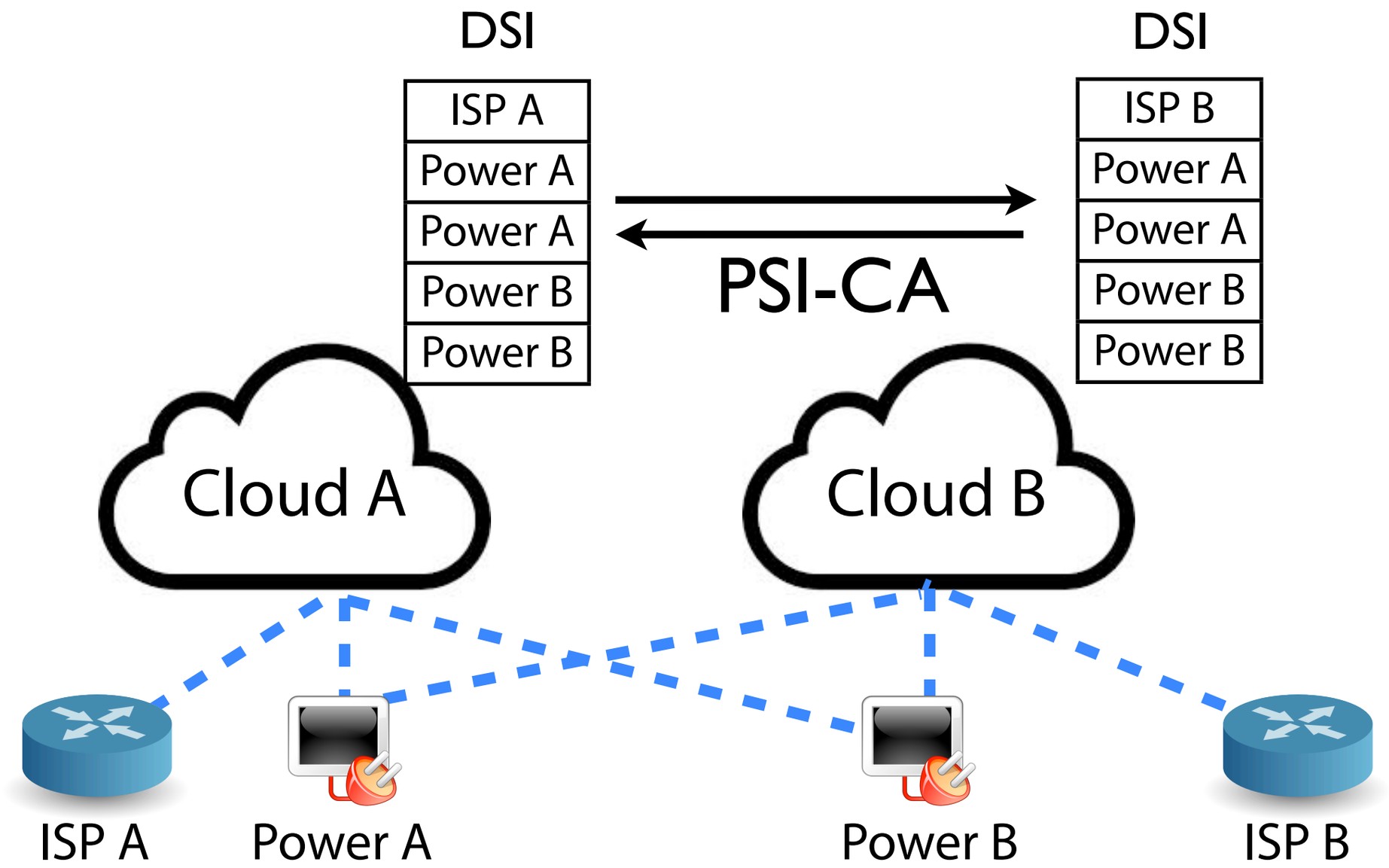
Using W-PSI-CA



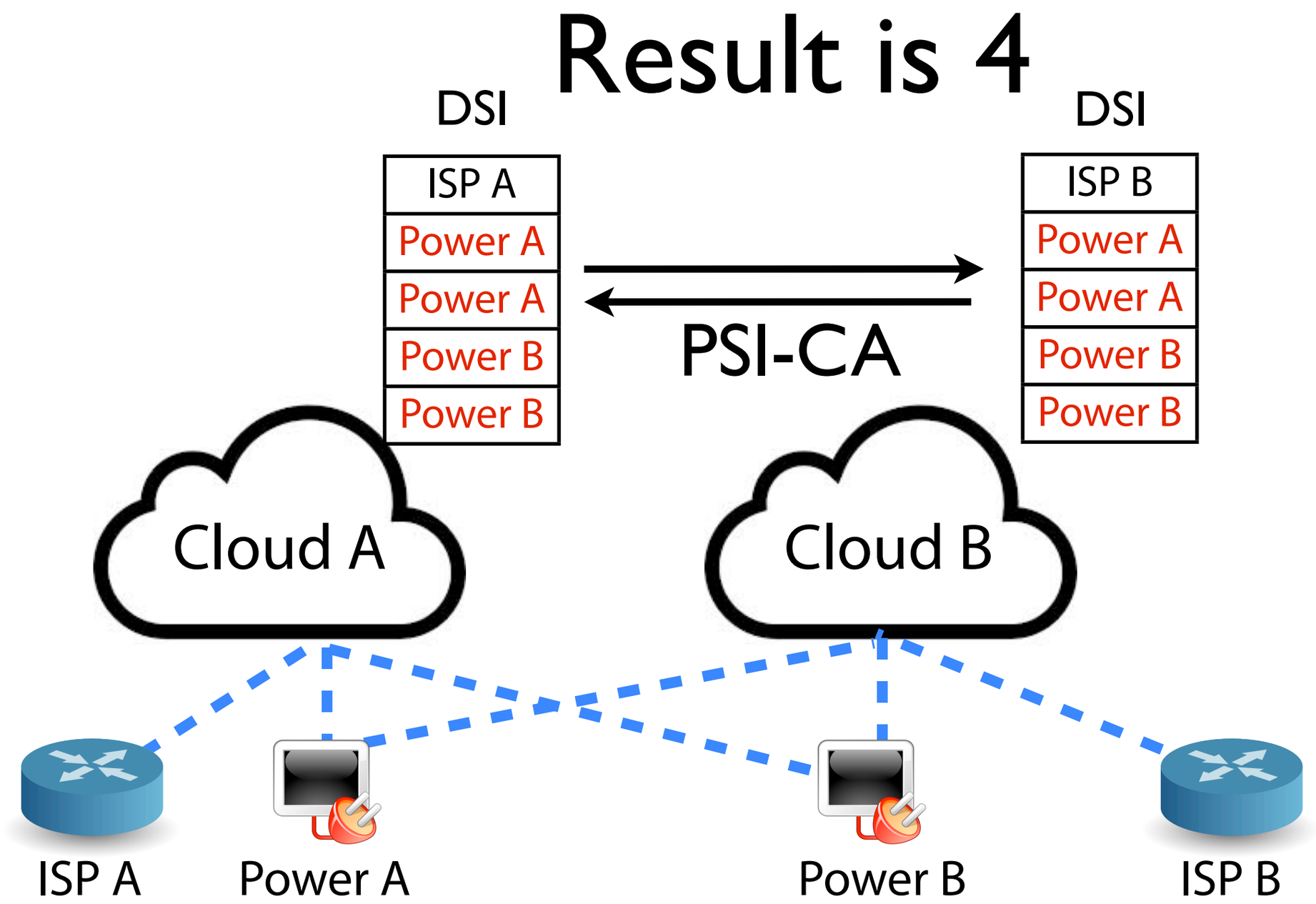
Using W-PSI-CA



Using W-PSI-CA



Using W-PSI-CA



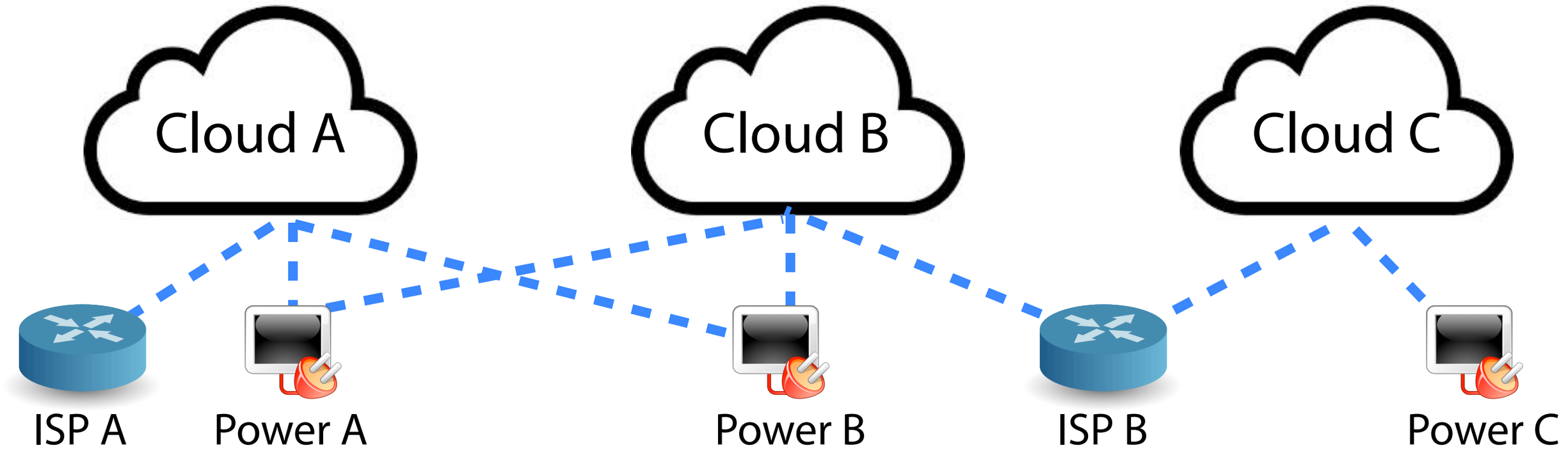
Case Study

Step 1

App Provider

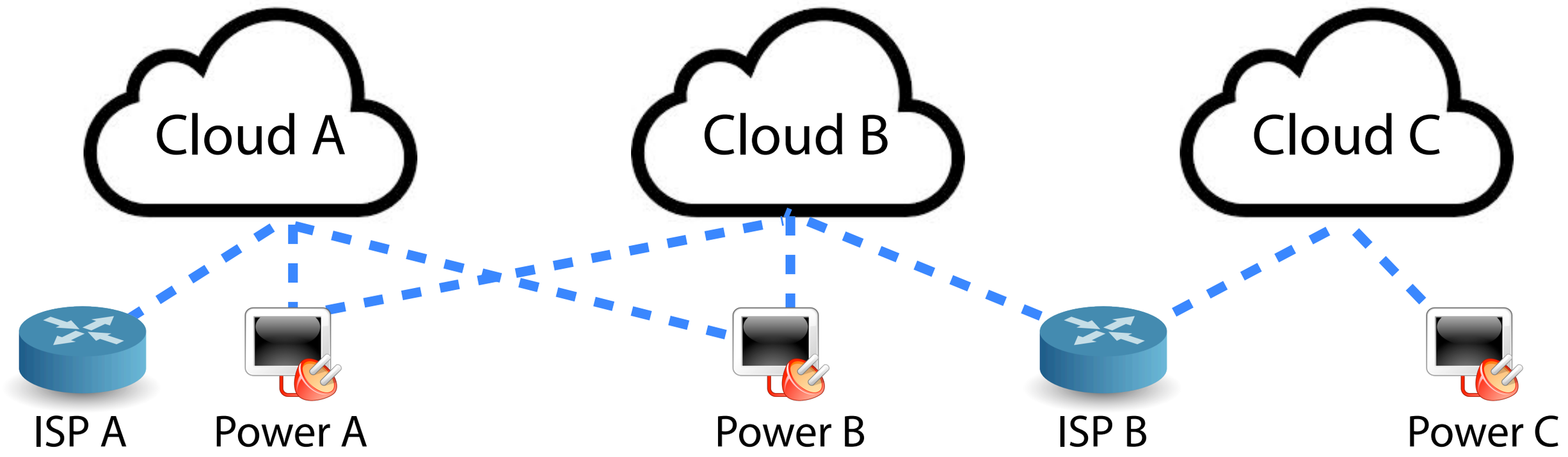
Select two clouds for redundancy: A&B? B&C? or A&C?

iRec

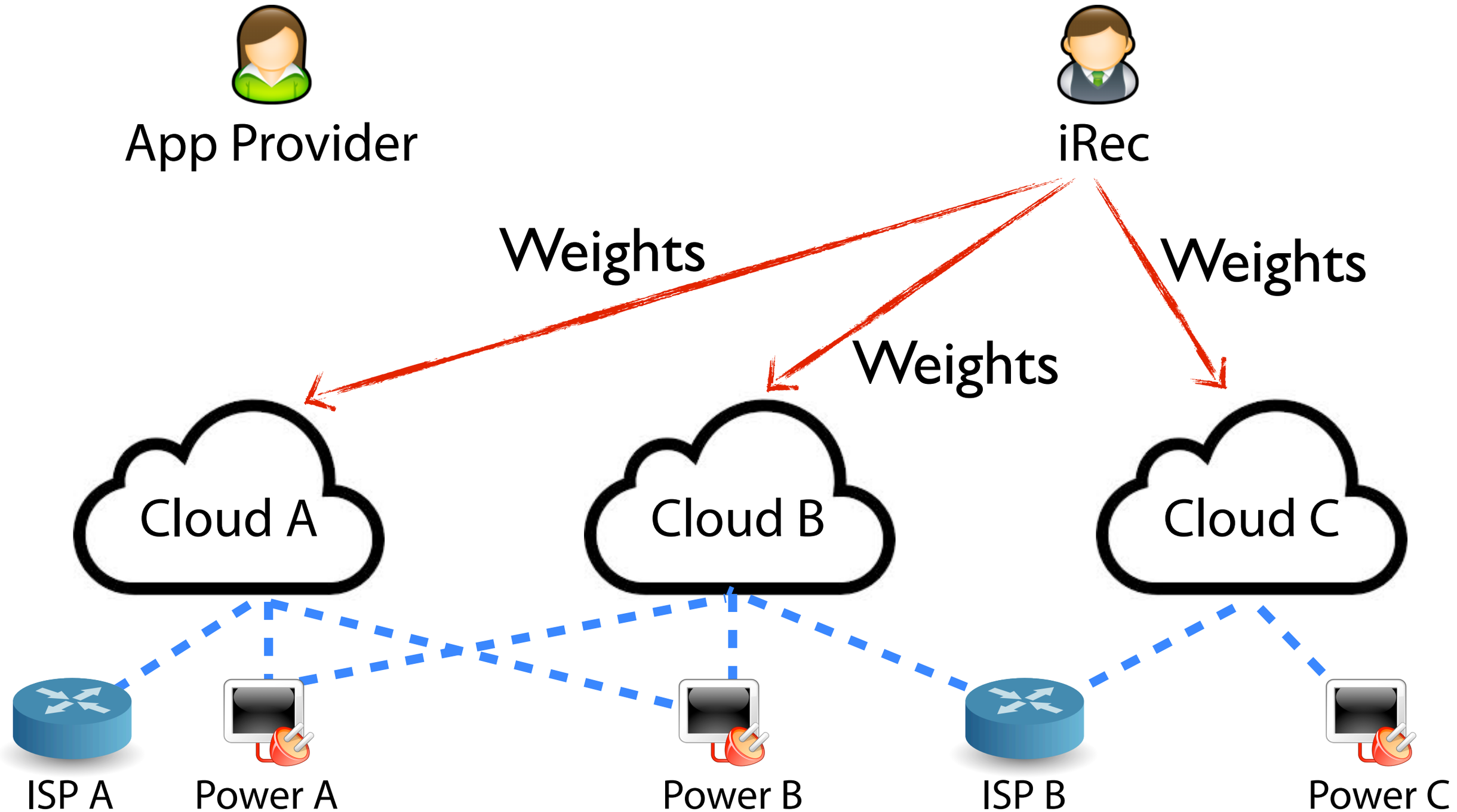


Step 1


App Provider
iRec


Cloud A
Cloud B
Cloud C
ISP A
Power A
Power B
ISP B
Power C

Step 2


App Provider
iRec
Weights
Weights
Weights
Cloud A
Cloud B
Cloud C
ISP A
Power A
Power B
ISP B
Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

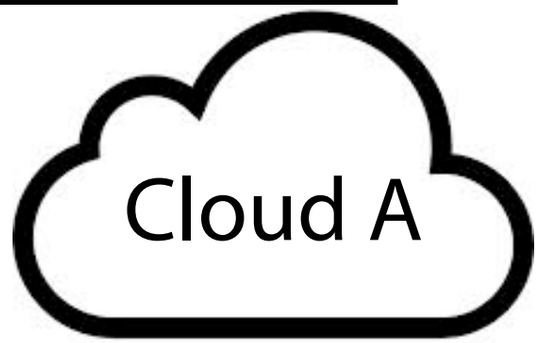
App Provider

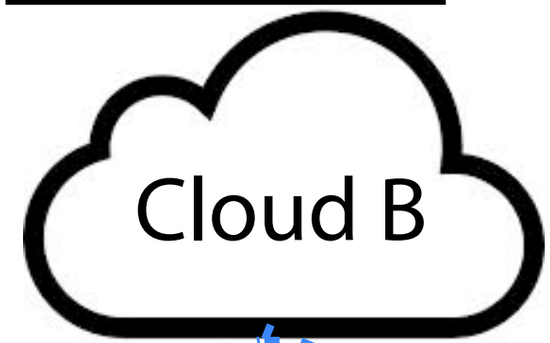
iRec

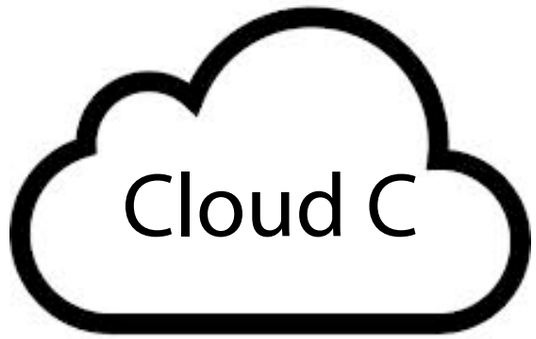
ISP A	3
Power A	1
Power B	1

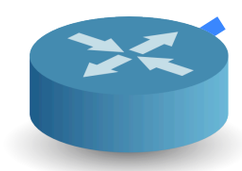
ISP B	3
Power A	1
Power B	1

ISP B	3
Power C	1





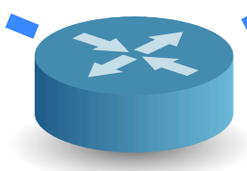




ISP A

Power A

Power B



ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

App Provider

iRec

ISP A	3
Power A	1
Power B	1

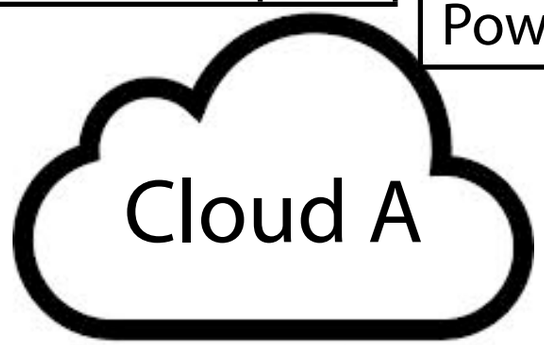
ISP A
ISP A
ISP A
Power A
Power B

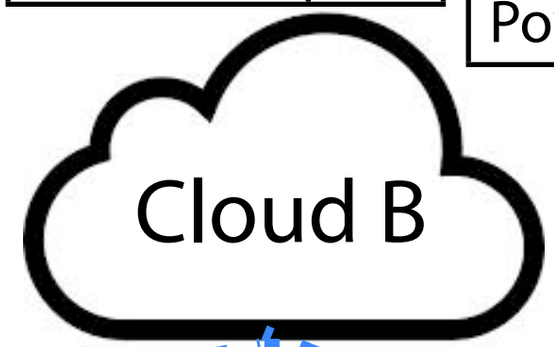
ISP B	3
Power A	1
Power B	1

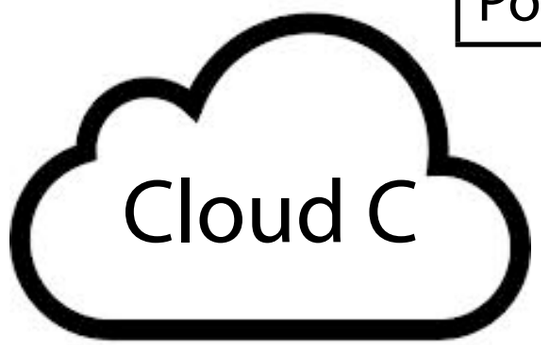
ISP B
ISP B
ISP B
Power A
Power B

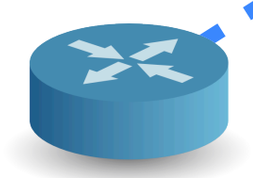
ISP B	3
Power C	1

ISP B
ISP B
ISP B
Power C









ISP A

Power A

Power B

ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

App Provider

iRec

ISP A
ISP A
ISP A
ISP A
Power A
Power B

ISP B
ISP B
ISP B
ISP B
Power A
Power B

ISP B
ISP B
ISP B
ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

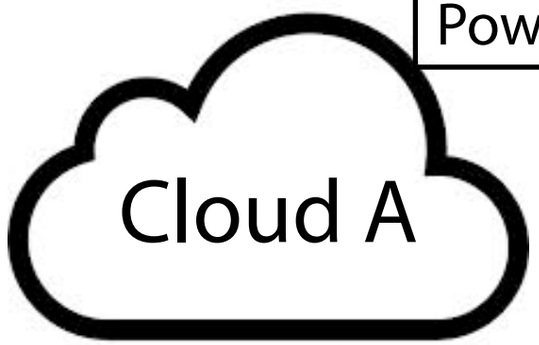
App Provider

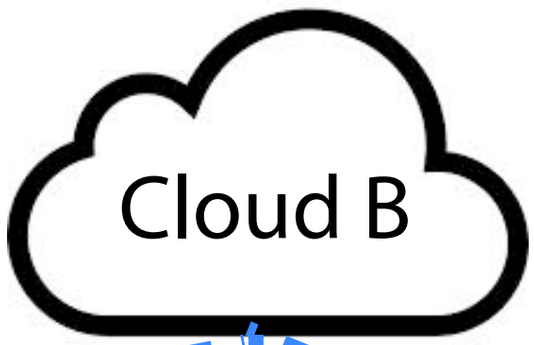
iRec

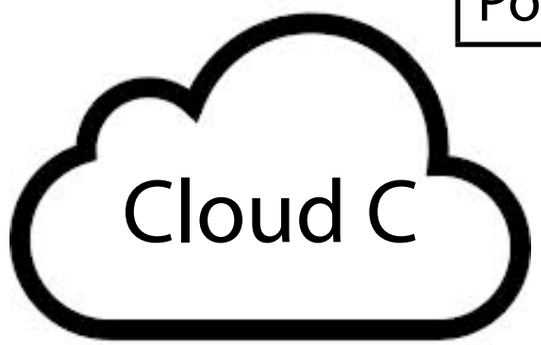
ISP A
ISP A
ISP A
Power A
Power B

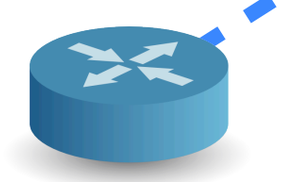
PSI-CA

ISP B
ISP B
ISP B
Power C





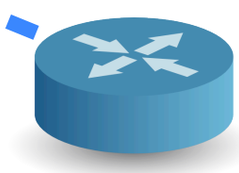




ISP A

Power A

Power B



ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

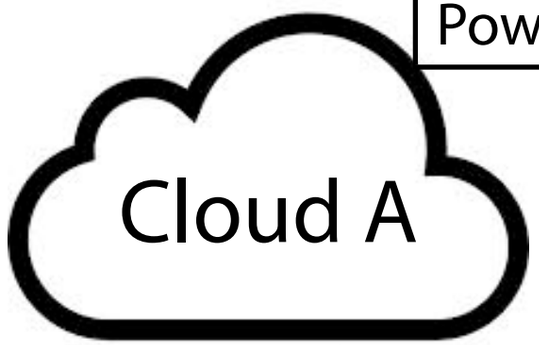
App Provider

iRec

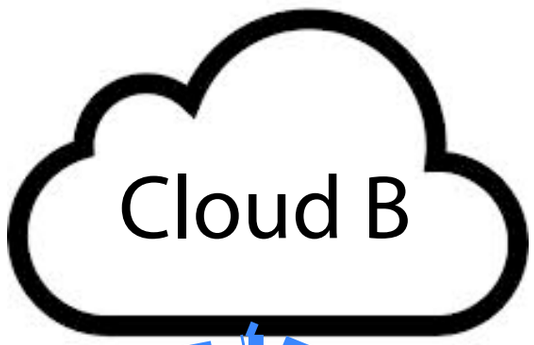
ISP A
ISP A
ISP A
Power A
Power B

PSI-CA

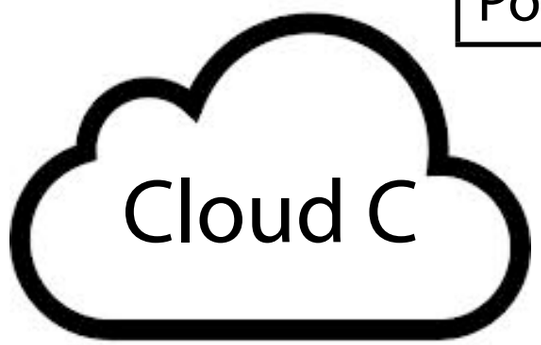
ISP B
ISP B
ISP B
Power C



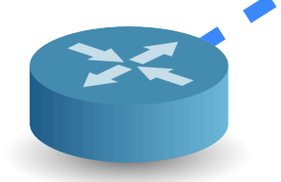
Cloud A



Cloud B



Cloud C



ISP A

Power A

Power B

ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	1
Cloud A, B	2

App Provider

iRec

ISP A
ISP A
ISP A
Power A
Power B

ISP B
ISP B
ISP B
Power A
Power B

PSI-CA

ISP B
ISP B
ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	3
Cloud A, B	2

App Provider

iRec

ISP A
ISP A
ISP A
Power A
Power B

ISP B
ISP B
ISP B
Power A
Power B

PSI-CA

ISP B
ISP B
ISP B
Power C

Cloud A

Cloud B

Cloud C

ISP A

Power A

Power B

ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	3
Cloud A, B	2

App Provider

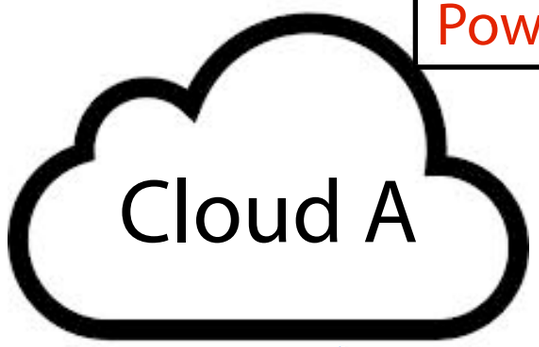
iRec

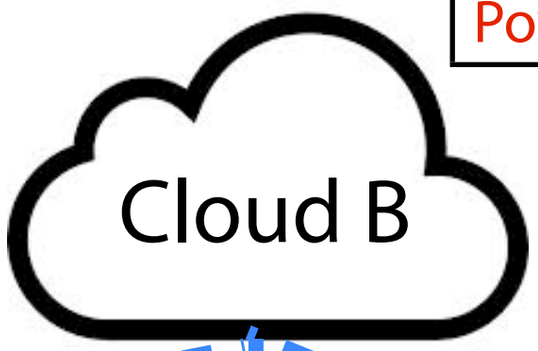
ISP A
ISP A
ISP A
Power A
Power B

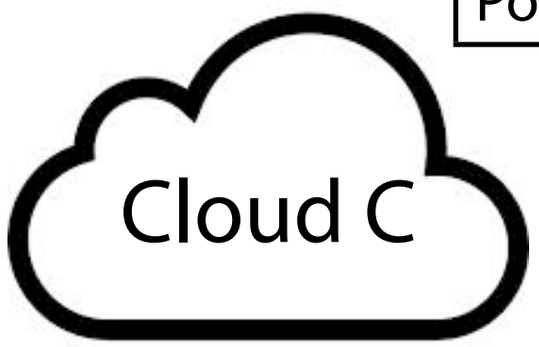
PSI-CA

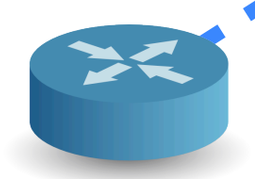
ISP B
ISP B
ISP B
Power A
Power B

ISP B
ISP B
ISP B
Power C





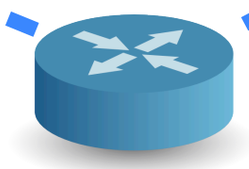




ISP A

Power A

Power B



ISP B

Power C

Step 3 & 4 with W-PSI-CA

Deployment	|∩|
Cloud A, C	0
Cloud B, C	3
Cloud A, B	2

App Provider

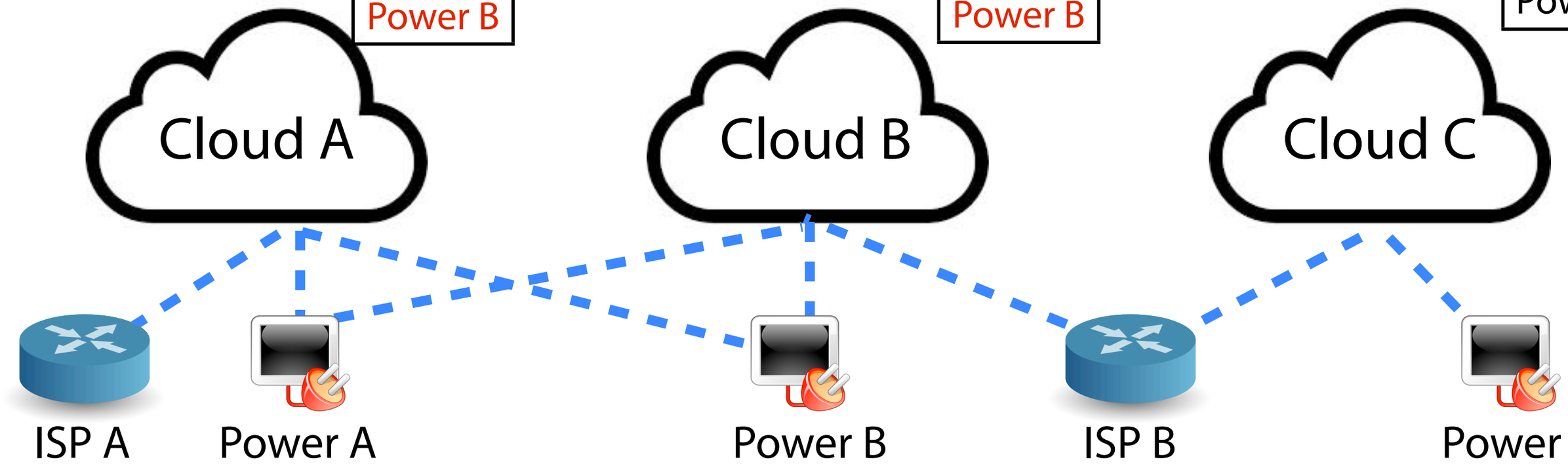
iRec

ISP A
ISP A
ISP A
Power A
Power B

PSI-CA

ISP B
ISP B
ISP B
Power A
Power B

ISP B
ISP B
ISP B
Power C

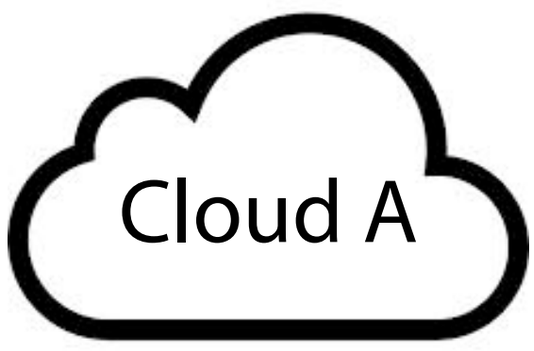


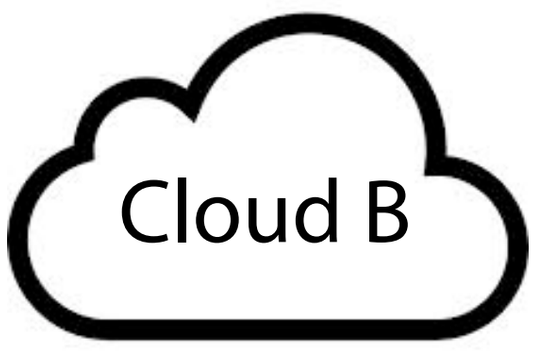
Step 5

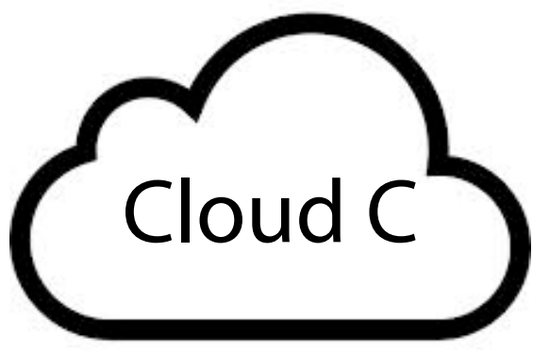
App Provider

iRec

Deployment	|∩|
Cloud A, C	0
Cloud B, C	3
Cloud A, B	2





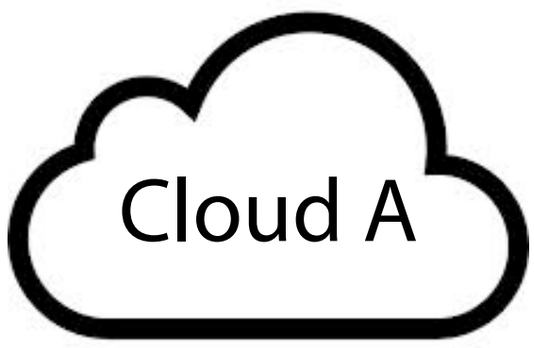


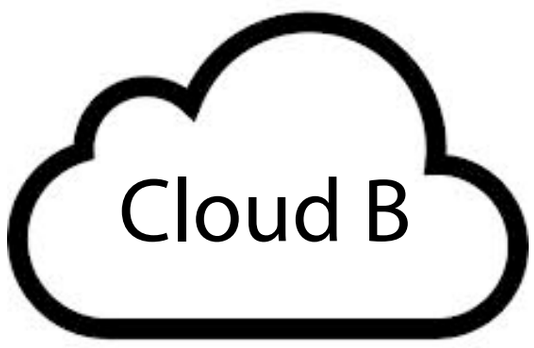
Step 5

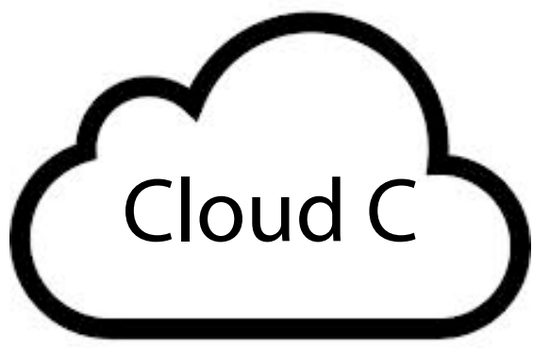
App Provider

iRec

Deployment	|∩|
Cloud A, C	0
Cloud B, C	3
Cloud A, B	2





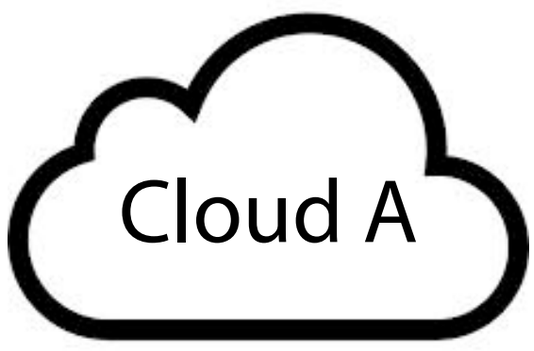


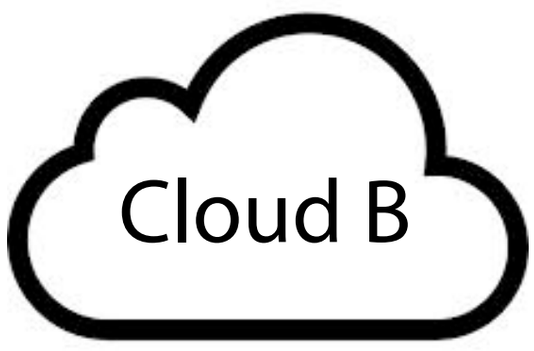
Step 5

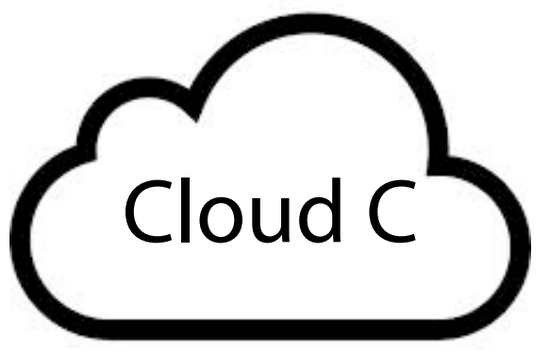
App Provider

iRec

Deployment	|∩|
Cloud A, C	0
Cloud A, B	2
Cloud B, C	3







Step 5

Deployment	|∩|
Cloud A, C	0
Cloud A, B	2
Cloud B, C	3

App Provider

Ranking List

iRec

Deployment	|∩|
1. Cloud A, C	0
2. Cloud A, B	2
3. Cloud B, C	3

Cloud A

Cloud B

Cloud C

Step 5

App Provider

Ranking List

iRec

Deployment	|∩|
1. Cloud A, C	0
2. Cloud A, B	2
3. Cloud B, C	3

Ranking list with W-PSI-CA

V.S.

Deployment	|∩|
1. Cloud A, C	0
2. Cloud B, C	1
3. Cloud A, B	2

Ranking list with PSI-CA

Road-Map

- Motivations
- Goal & Insight
- iRec System
- Next Steps

Road-Map

- Motivations
- Goal & Insight
- iRec System
- Next Steps

Next Steps

- Can we provide stronger privacy preservation?

Next Steps

- Can we provide stronger privacy preservation?
- Do cloud providers have incentives to join?

Next Steps

- Can we provide stronger privacy preservation?
- Do cloud providers have incentives to join?
- Will the clouds behave honestly?

Next Steps

- Can we provide stronger privacy preservation?
- Do cloud providers have incentives to join?
- Will the clouds behave honestly?
- Can we make iRec more scalable?
- How do we evaluate iRec with realistic cloud dependency datasets?

Thanks!

Questions?