Secure Serverless Computing
using Dynamic Information Flow Control

Kalev Alpernas, Cormac Flanagan, Sadjad Fouladi, Leonid Ryzhyk, Mooly Sagiv, Thomas Schmitz, and Keith Winstein

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The Cloud is Growing Faster than Ever

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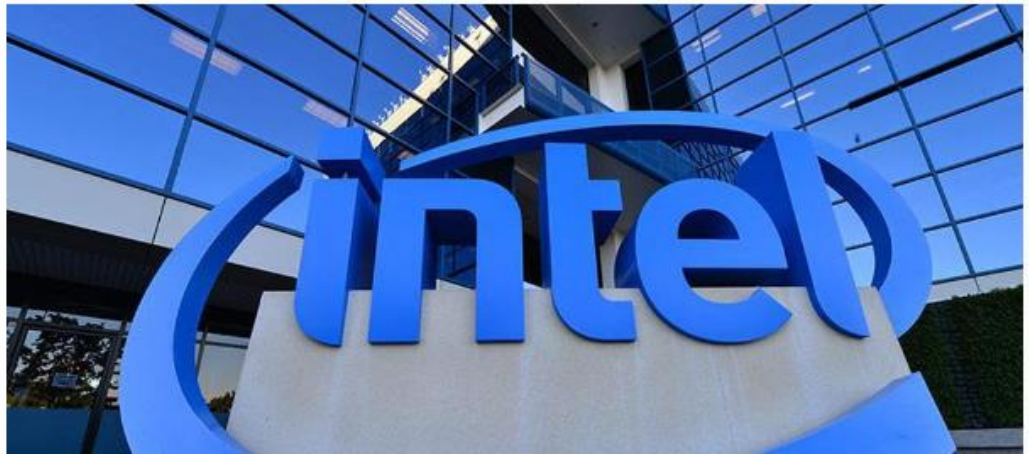
2,451 views | Oct 27, 2018, 06:00pm

Stellar Intel Earnings Underscore Tech Sector Strength, Enormous Growth Potential In The Cloud

Dave Altavilla Contributor

Consumer Tech

I cover break-out tech in mobile, on desktop and in the data center.



The Cloud is Growing Faster than Ever

Forbe

Strong Cloud Growth Continues to Drive Microsoft Higher

Growth was strong across all segments, but Azure was still the highlight.

Danny Vena (TMFLifeIsGood)
Oct 28, 2018 at 10:37AM

Over the past several years, **Microsoft** (NASDAQ:MSFT) has accomplished an amazing feat, transforming from a shrink-wrapped business software provider to one of the biggest names in cloud computing. The company has been successful challenging the cloud leader, **Amazon** Web Services, and making meaningful headway, currently ranking in a strong second place.

As the global digital transformation gains steam, investors were watching closely for signs that Microsoft's cloud momentum would continue. When the company reported the financial results of its fiscal 2019 first quarter, which ended Sept. 30, 2018, Microsoft showed that it has much more growth in the tank, producing a record first quarter.

AUTHOR

Danny Vena
(TMFLifeIsGood)

Daniel W. Vena, CPA, CGMA is long-term investor searching for intangibles that provide explosive growth opportunities in his investments. He served on active duty with the US Army and has a Bachelors degree in accounting.

Follow @dannyvena 335 followers

ARTICLE INFO

Oct 28, 2018 at 10:37AM

Technology and Telecom

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18,495 views | Jan 7, 2018, 07:36pm

83% Of Enterprise Workloads Will Be In The Cloud By 2020

Louis Columbus Contributor

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- Digitally transforming enterprises (63%) is the leading factor driving greater public cloud engagement or adoption today.
- 66% of IT professionals say security is their most significant concern in adopting an enterprise cloud computing strategy.

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CLOUD | Back to Home

Is security now a driver of cloud adoption?

JAMES NUNNS EDITOR
23RD OCTOBER 2017

+ INCREASE / DECREASE T

The Internet is a Leaky Place

CNN BUSINESS Markets Tech Media Success Perspectives Video U.S. Edition +

Facebook just had its worst hack ever – and it could get worse

By Donie O'Sullivan, CNN Business

Updated 9:22 AM ET, Thu October 4, 2018

New York (CNN) – On Sunday, September 16, engineers at Facebook detected some unusual activity on the social media platform's networks. It was an attack, the biggest security breach in Facebook's history. And it would take the company 11 more days to stop it.

Now, almost a week since the public was first told of the attack, we still barely know anything about what happened.

We don't know who the hackers were, or what they were looking for. We don't know whether they were targeting particular people in certain countries. We don't know how long they had access to users' information. And we don't know what, if anything, they took.

The Internet is a Leaky Place

CNN BUSINESS Markets Tech Media Success Perspectives Video U.S. Edition +

Cathay Pacific got hacked, compromising the data of millions of passengers

By Jethro Mullen, CNN Business

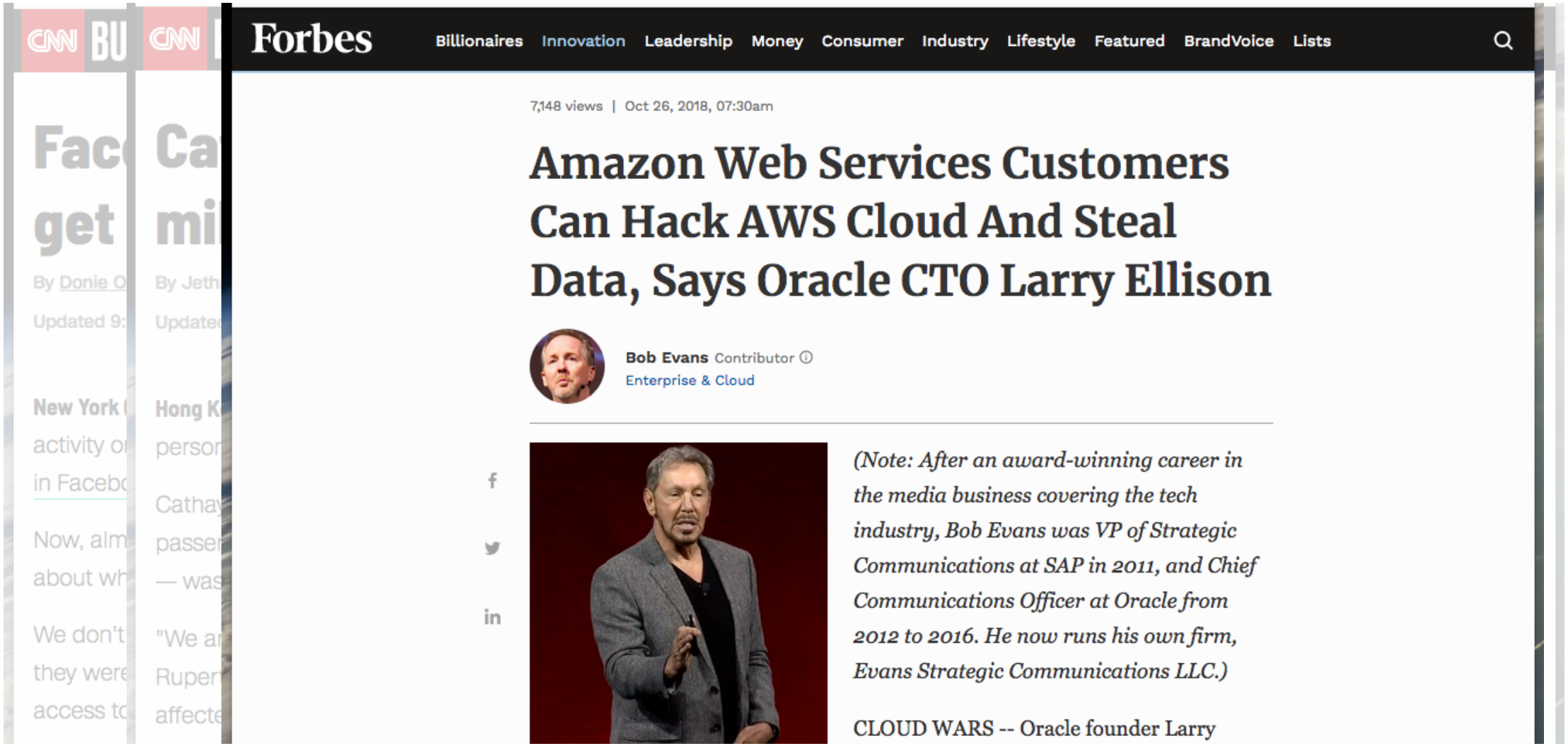
Updated 12:22 AM ET, Thu October 25, 2018

Hong Kong (CNN Business) – One of Asia's top airlines has discovered a data breach in which the personal information of more than 9 million passengers may have been stolen.

Cathay Pacific (CPCAY) said late Wednesday that a wide range of data — including passengers' names, dates of birth, phone numbers, email addresses and passport numbers — was exposed in a hack of its information systems earlier this year.

"We are very sorry for any concern this data security event may cause our passengers," CEO Rupert Hogg said in a statement. The Hong Kong-based carrier is in the process of contacting affected people, he added.

The Internet is a Leaky Place



Forbes

Billionaires Innovation Leadership Money Consumer Industry Lifestyle Featured BrandVoice Lists

7,148 views | Oct 26, 2018, 07:30am

Amazon Web Services Customers Can Hack AWS Cloud And Steal Data, Says Oracle CTO Larry Ellison

Bob Evans Contributor
Enterprise & Cloud

(Note: After an award-winning career in the media business covering the tech industry, Bob Evans was VP of Strategic Communications at SAP in 2011, and Chief Communications Officer at Oracle from 2012 to 2016. He now runs his own firm, Evans Strategic Communications LLC.)

CLOUD WARS -- Oracle founder Larry

The Internet is a Leaky Place

Healthcare IT News

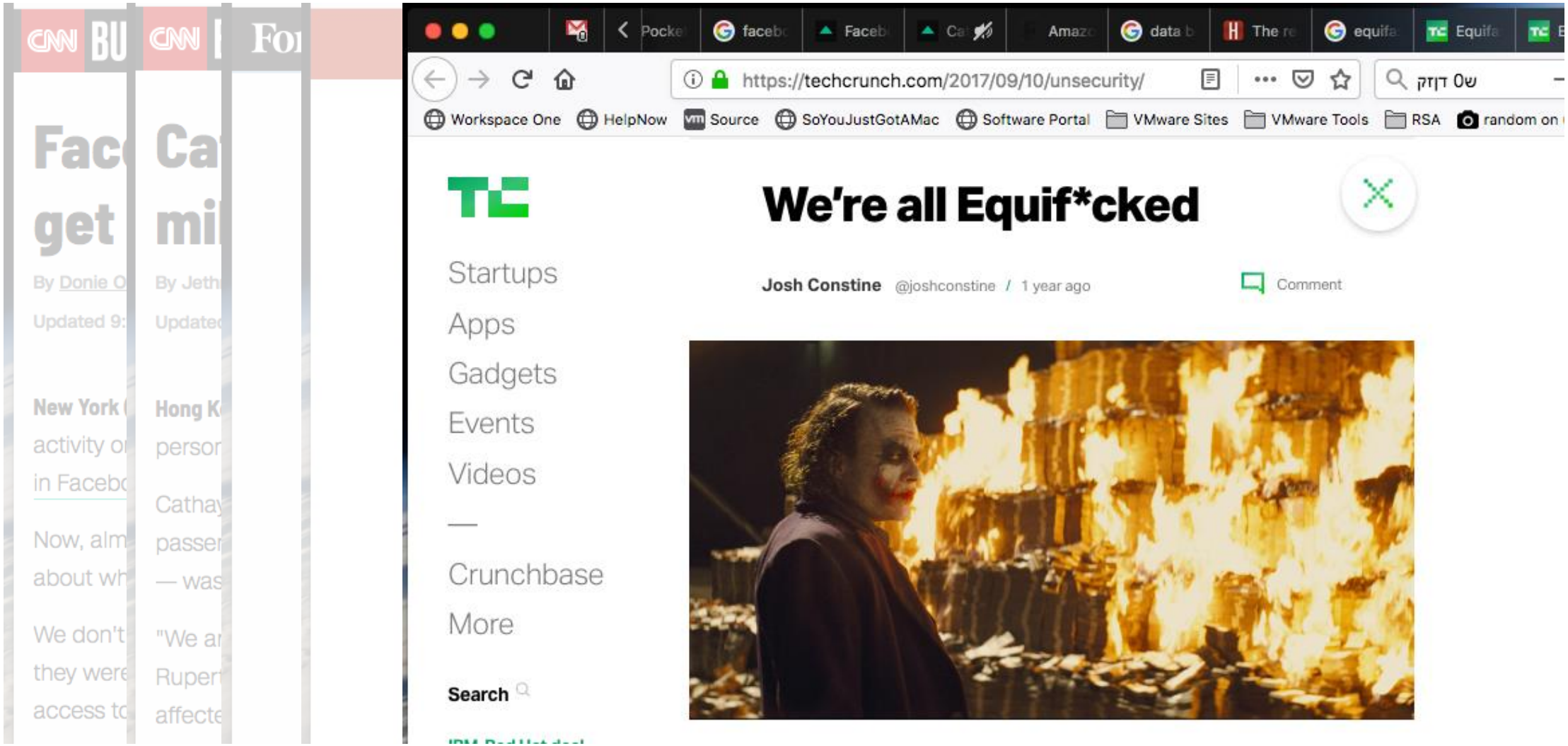
GLOBAL EDITION TOPICS SIGN UP MAIN MENU

The real victim in health data breaches? Patients' medical identities

By Jessica Davis | October 29, 2018 | 05:03 PM

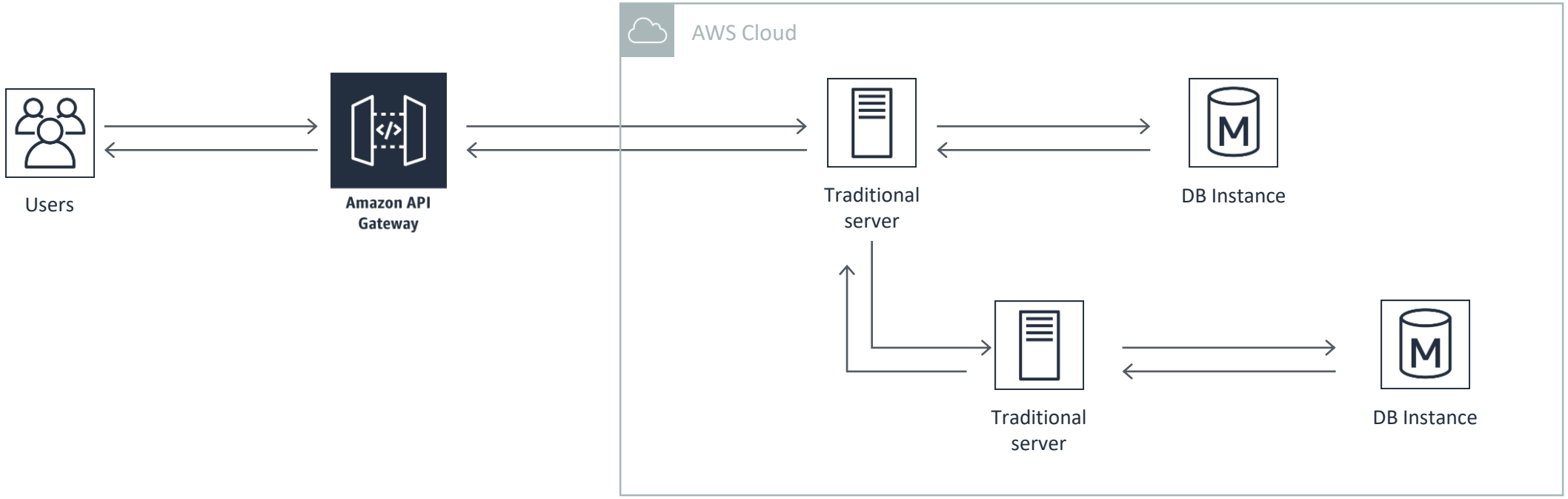
Hackers can perform synthetic identify theft long after a cybersecurity event by piecing together data to conduct medical and insurance fraud.

The Internet is a Leaky Place



Cloud Applications

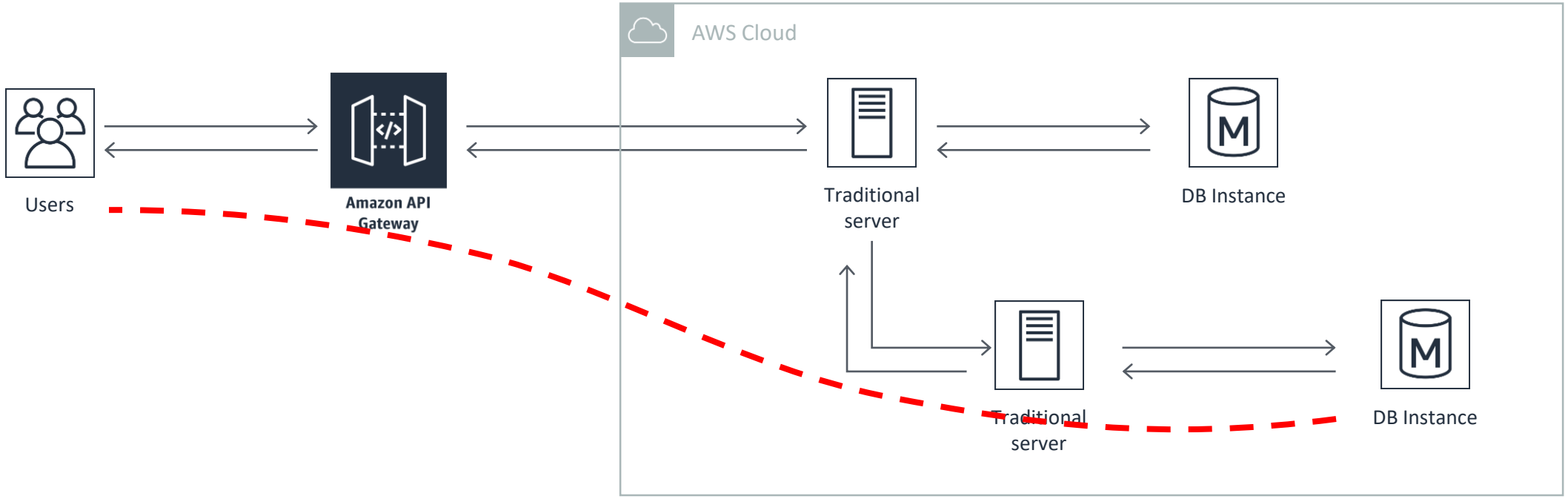
Traditional (monolithic) three tiered application



Cloud Applications

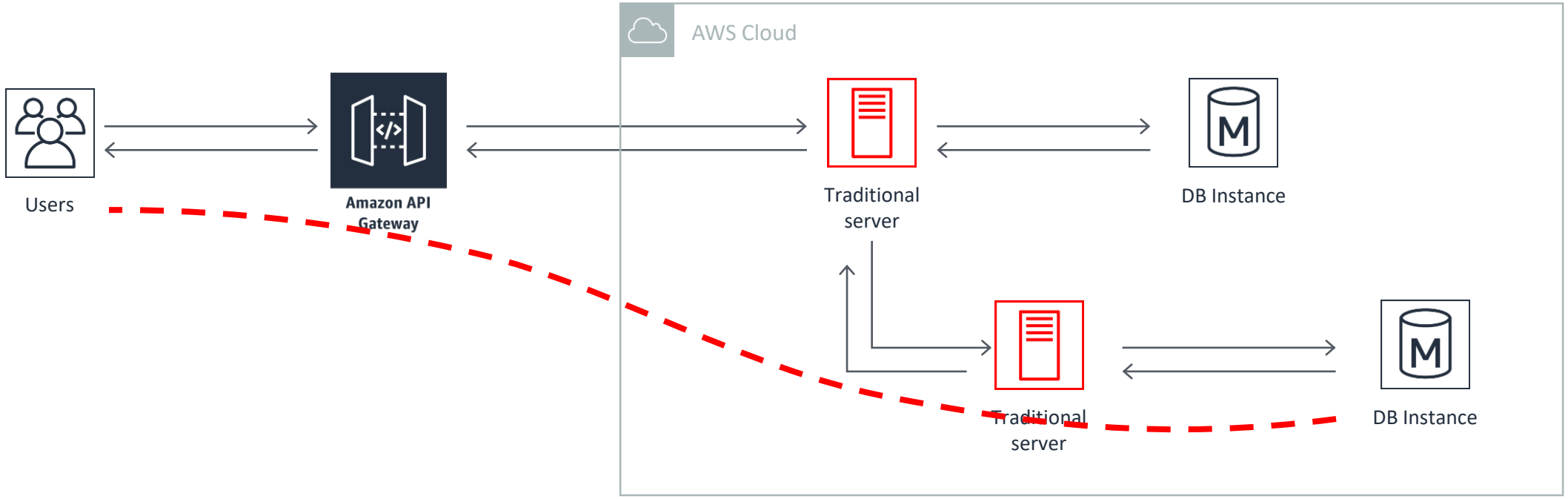
Goal: keep data secure – Information Flow Control (IFC)

Non-Interference



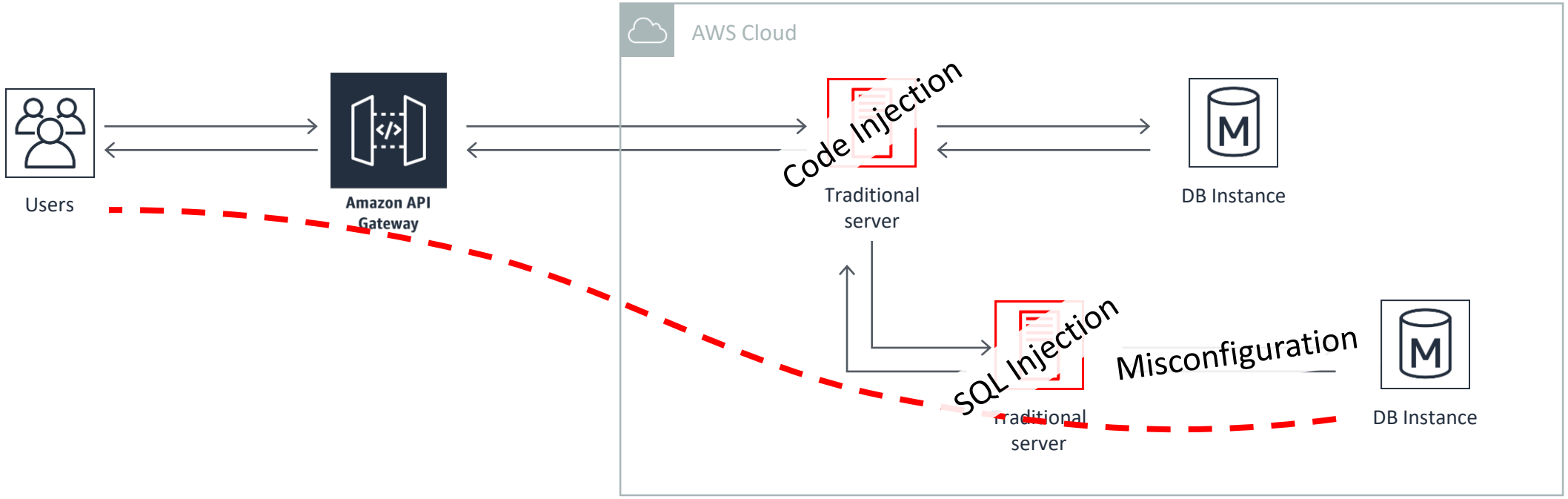
Cloud Applications

Servers are vulnerable



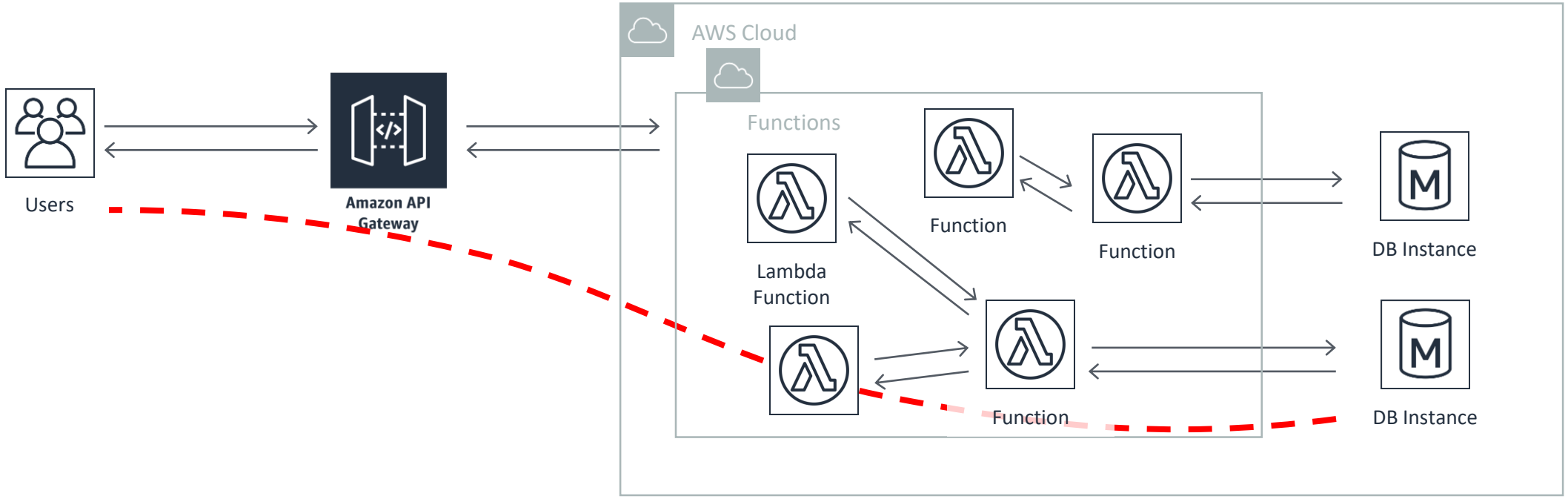
Cloud Applications

Servers are vulnerable



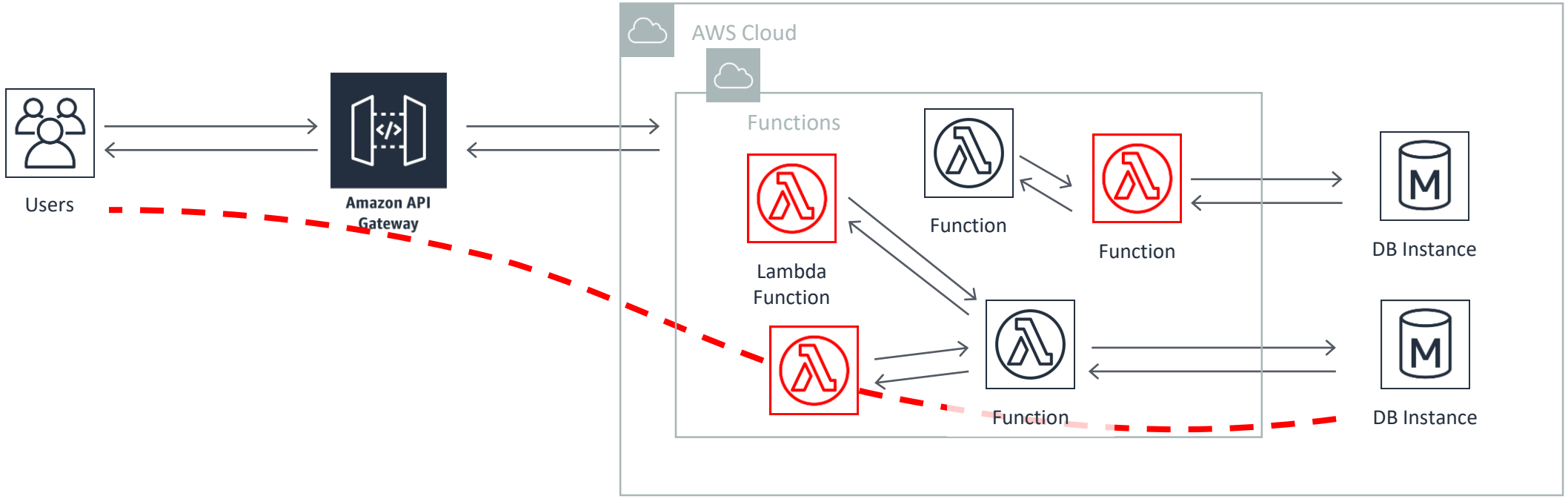
Cloud Applications

What happens when we replace them with serverless functions?



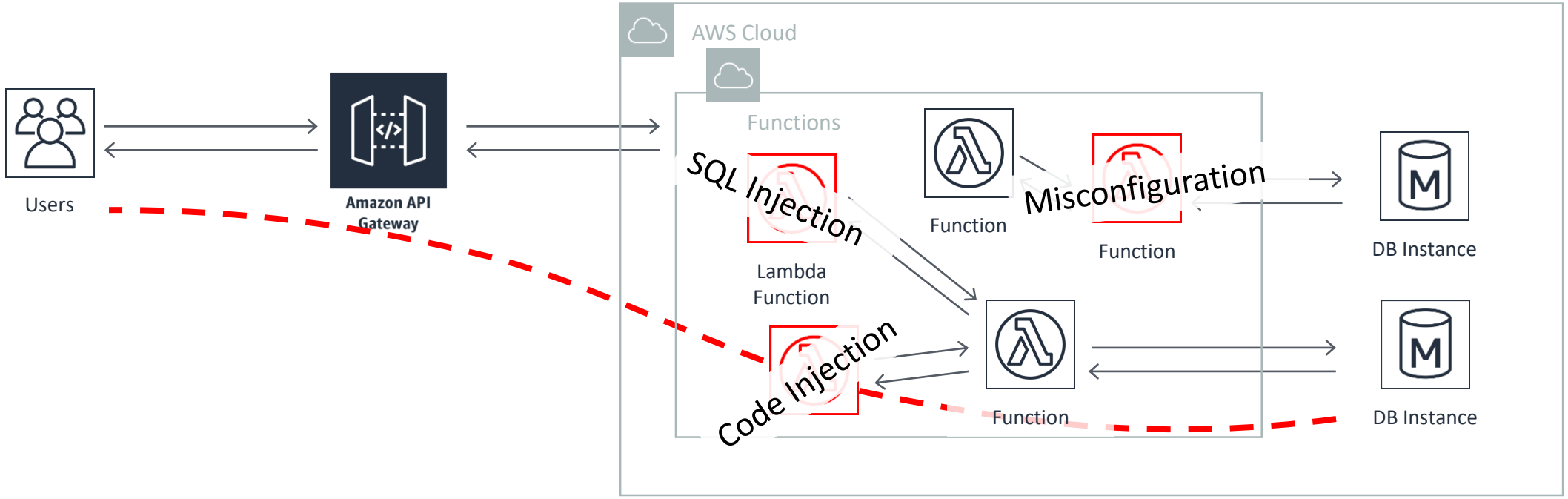
Cloud Applications

Functions are vulnerable



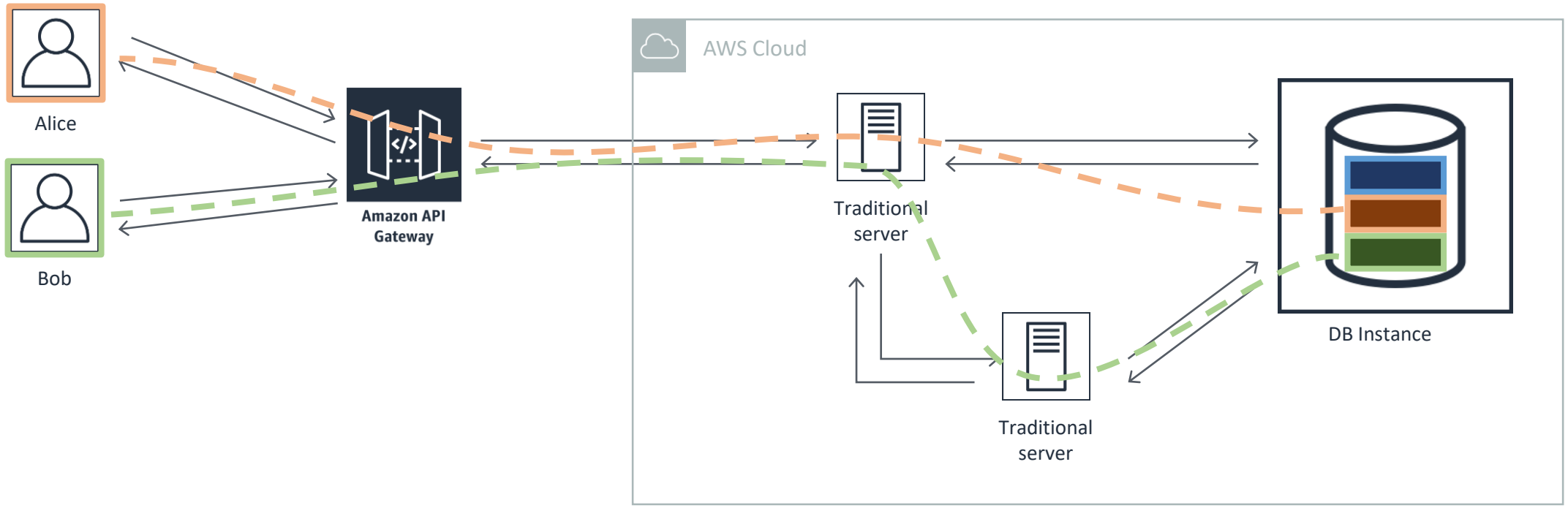
Cloud Applications

Polyglot, distributed environment makes things even harder



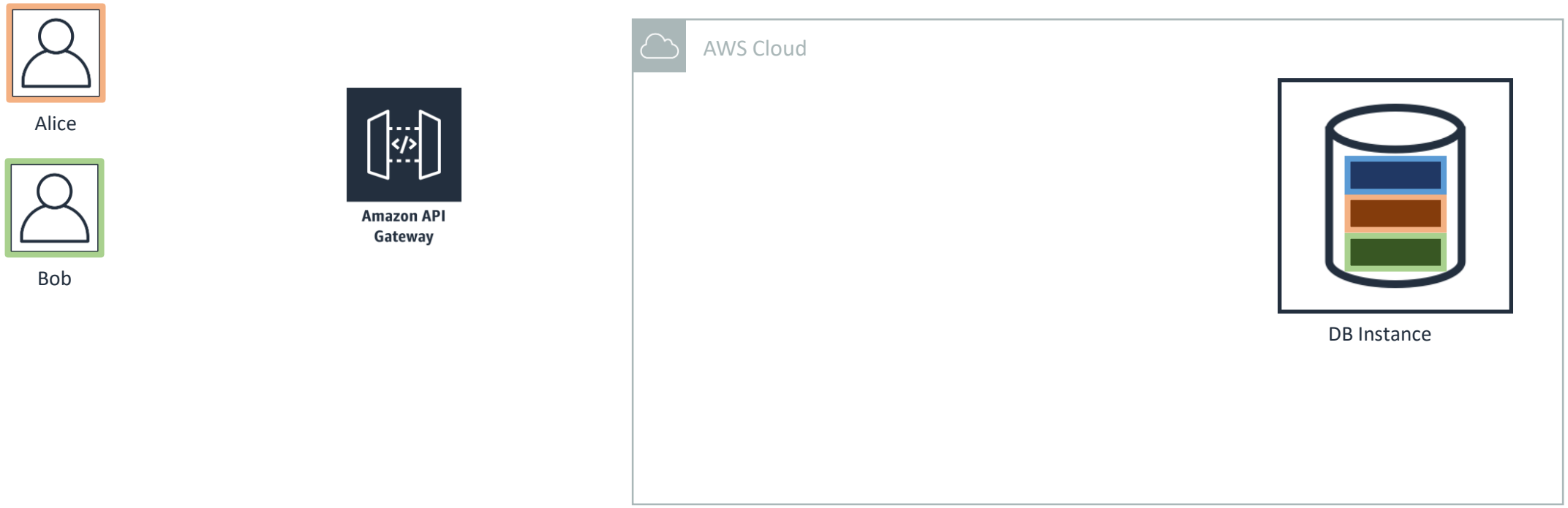
Monolithic Applications

Long running processes, serving multiple users, managing complex local state



Serverless Applications

Every execution serves a single request, no local state



Serverless Applications

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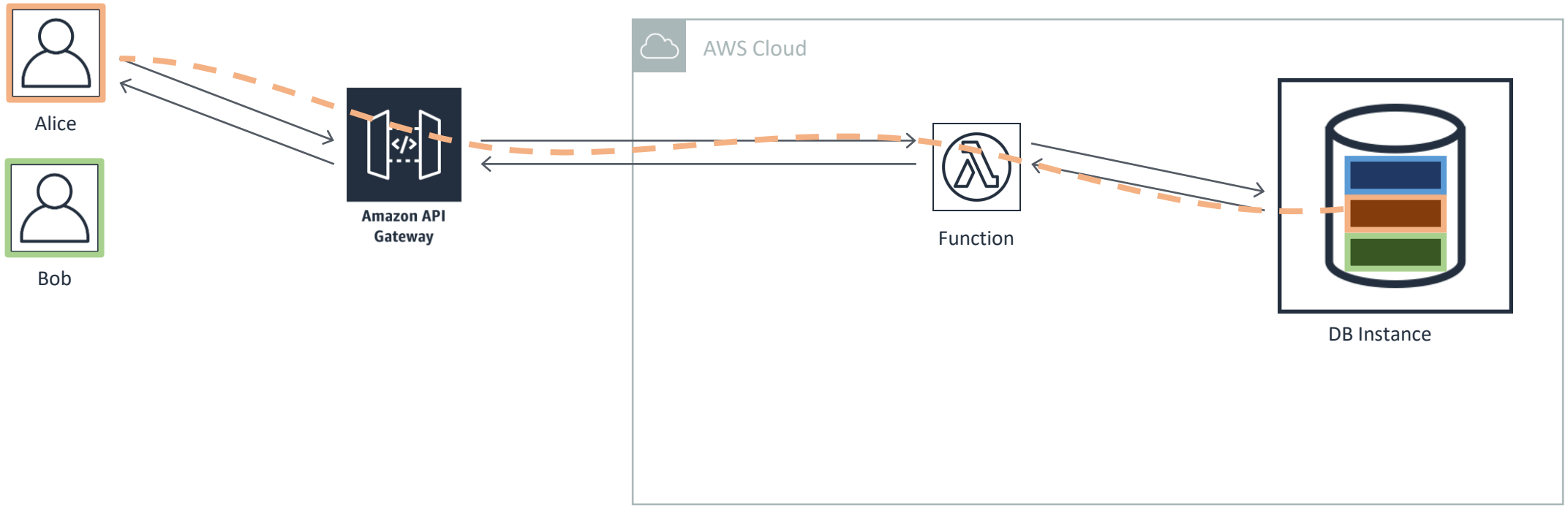

Serverless Applications

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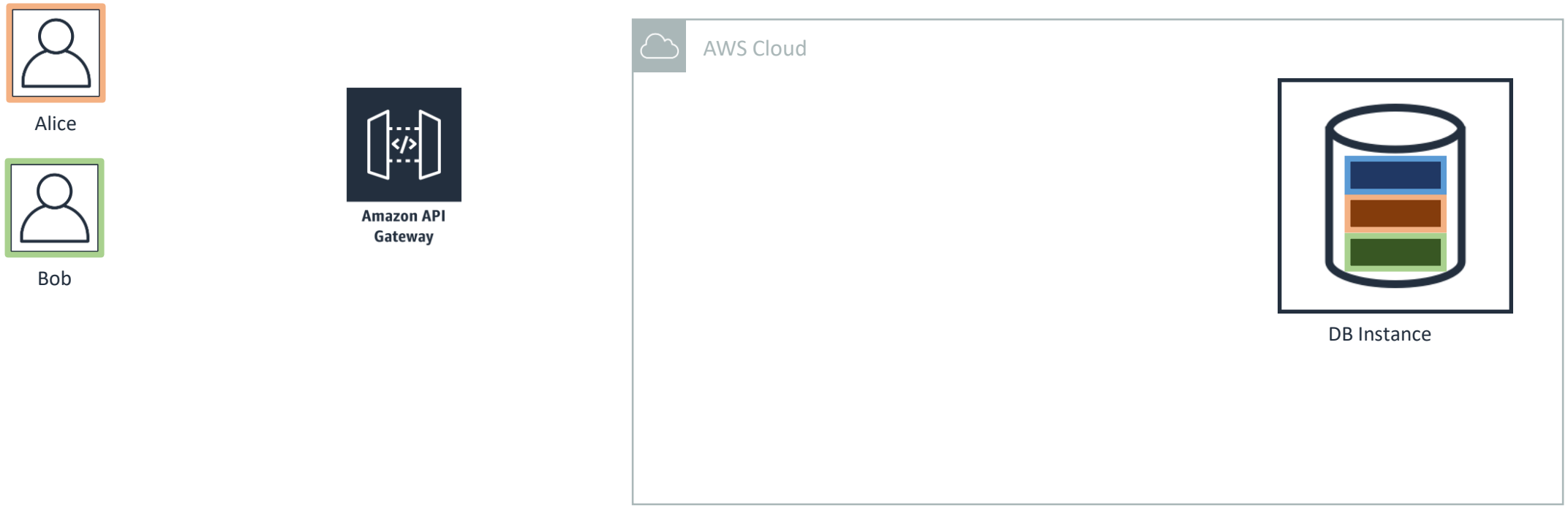

Serverless Applications

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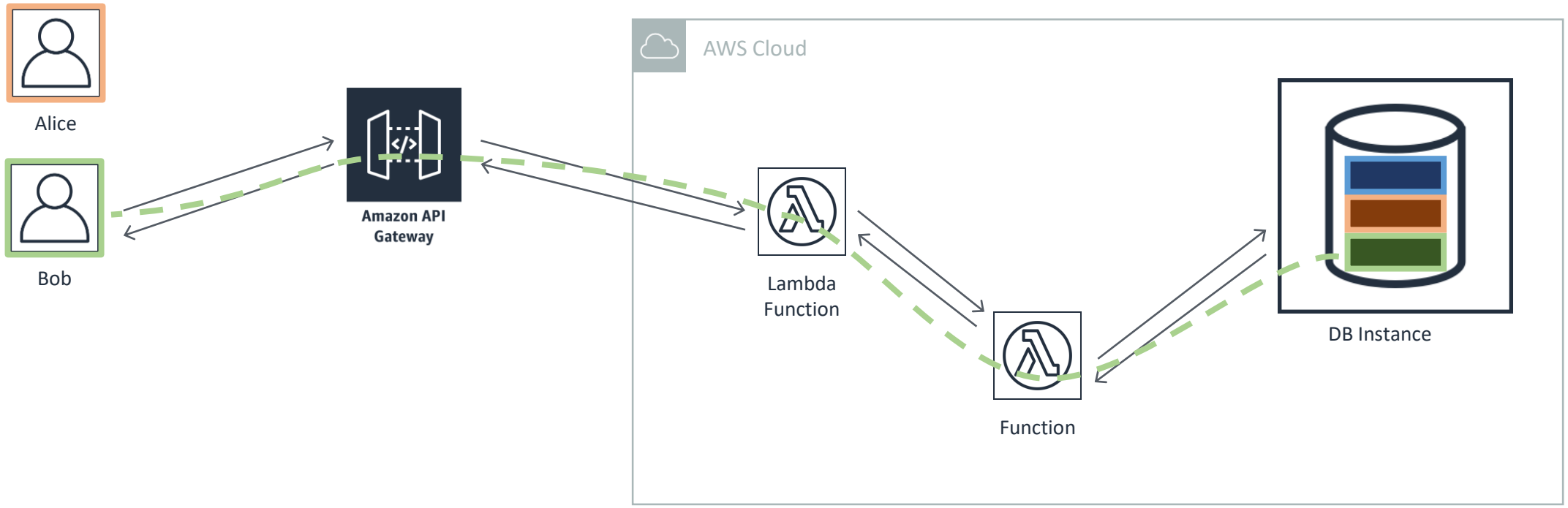

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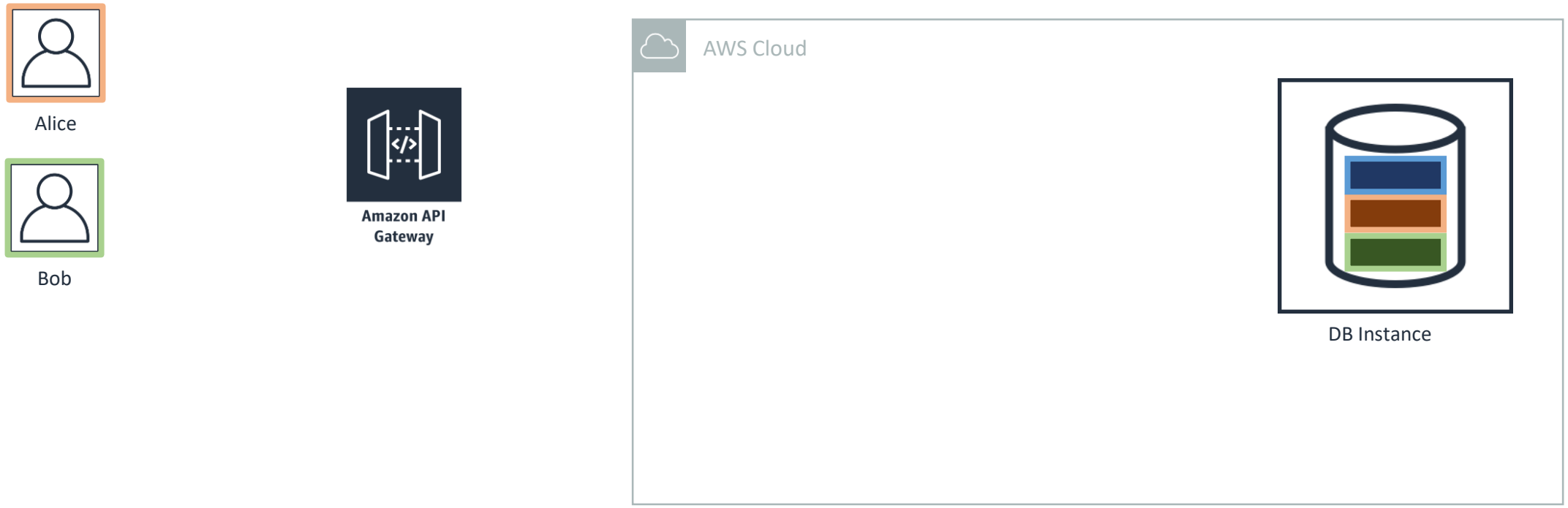


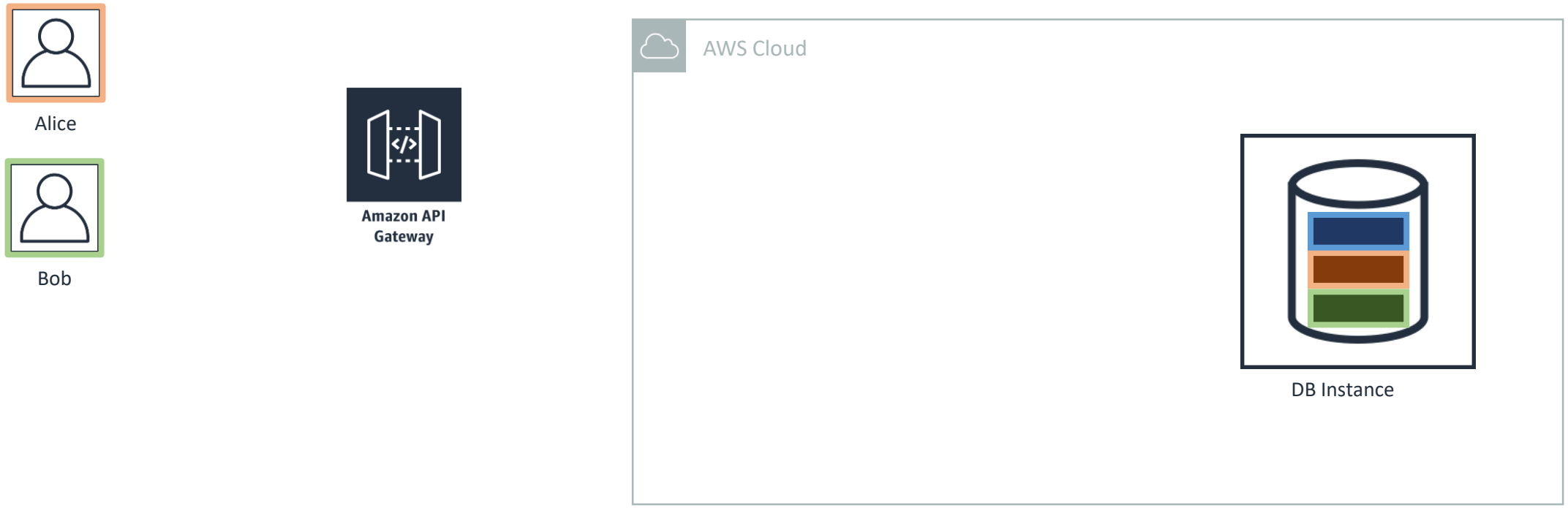
Underneath Everything, there is Hope

Serverless computing is our opportunity to implement **efficient IFC**

Perform IFC tracking at **function boundaries**

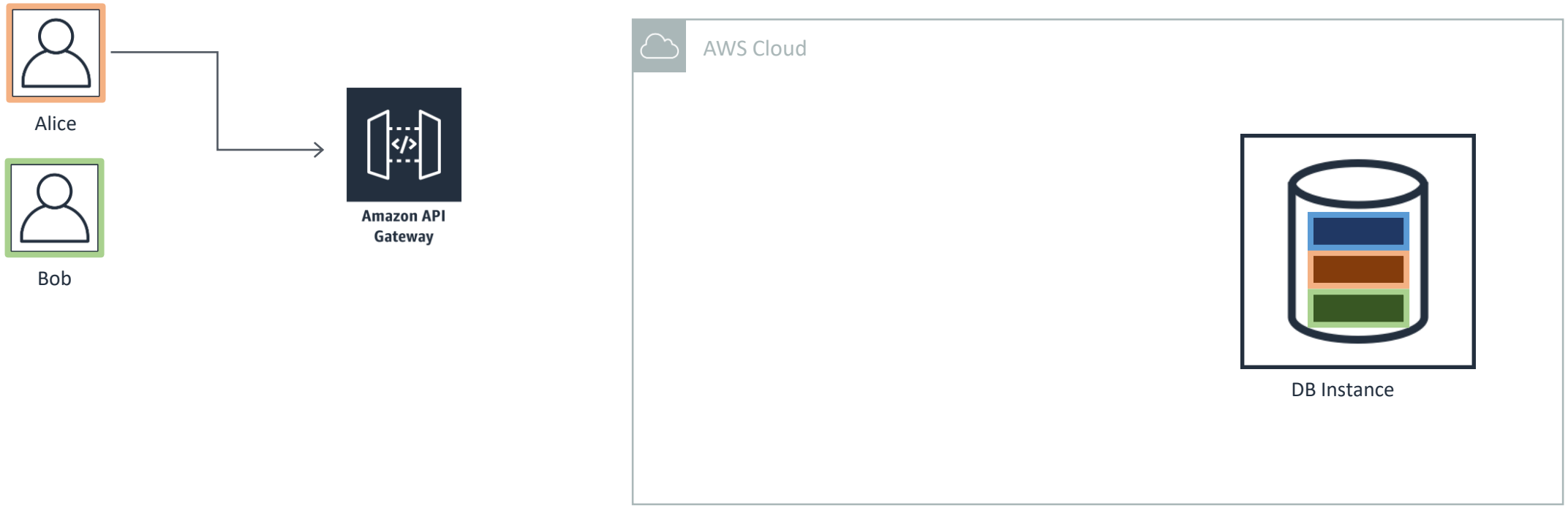
Serverless+IFC

How do we exploit Serverless to design an efficient IFC system?



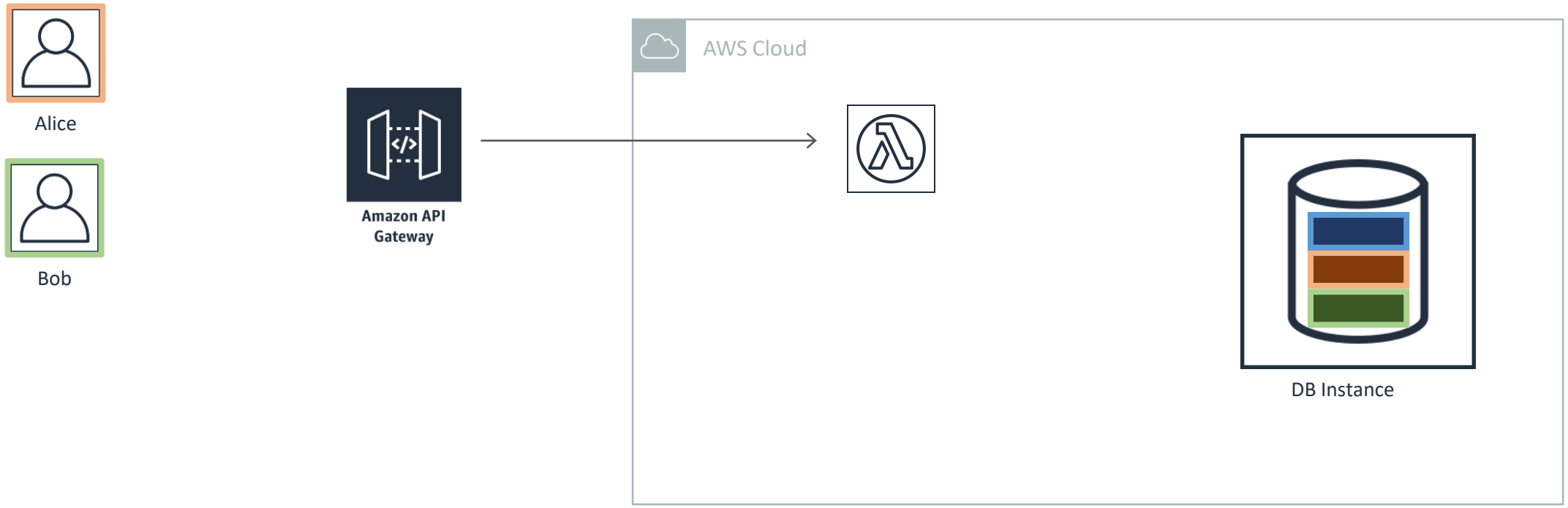
Serverless+IFC

Alice makes a request



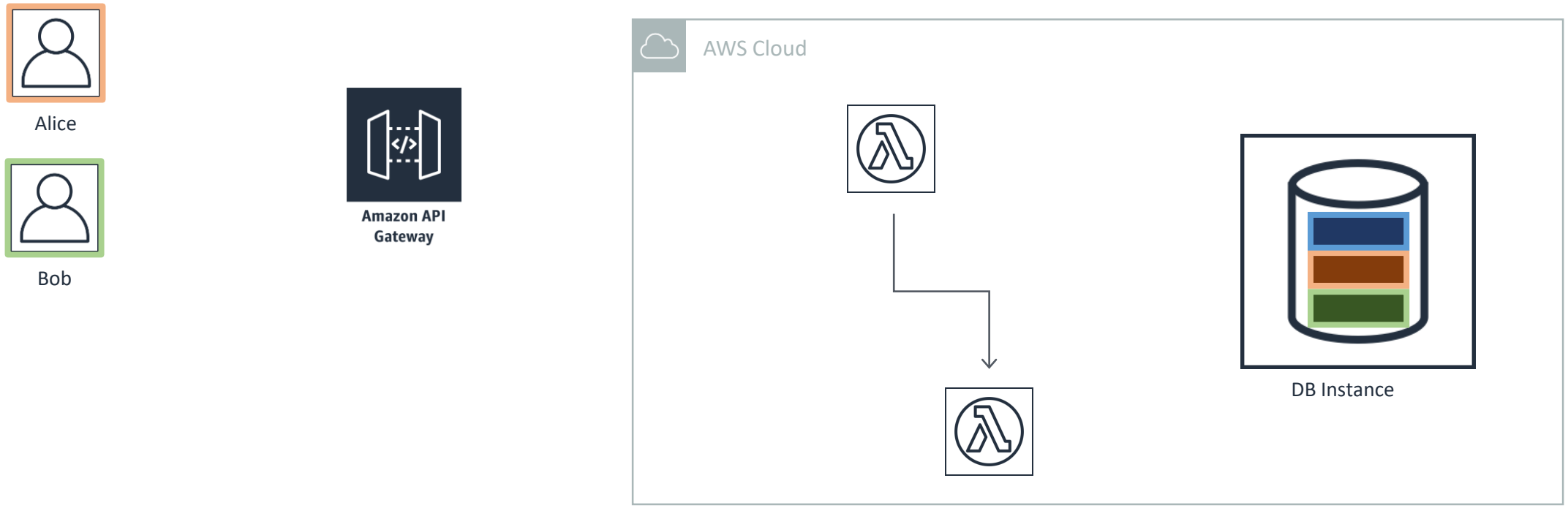
Serverless+IFC

The Serverless framework spawns a function to serve the request



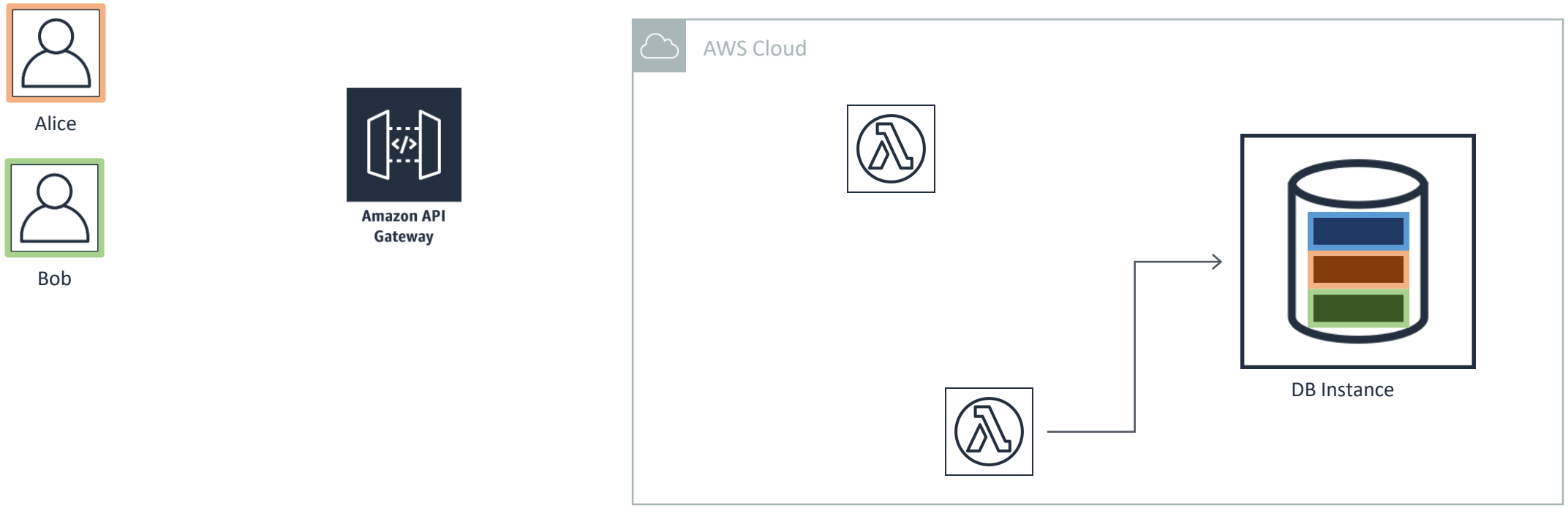
Serverless+IFC

Functions may spawn additional functions



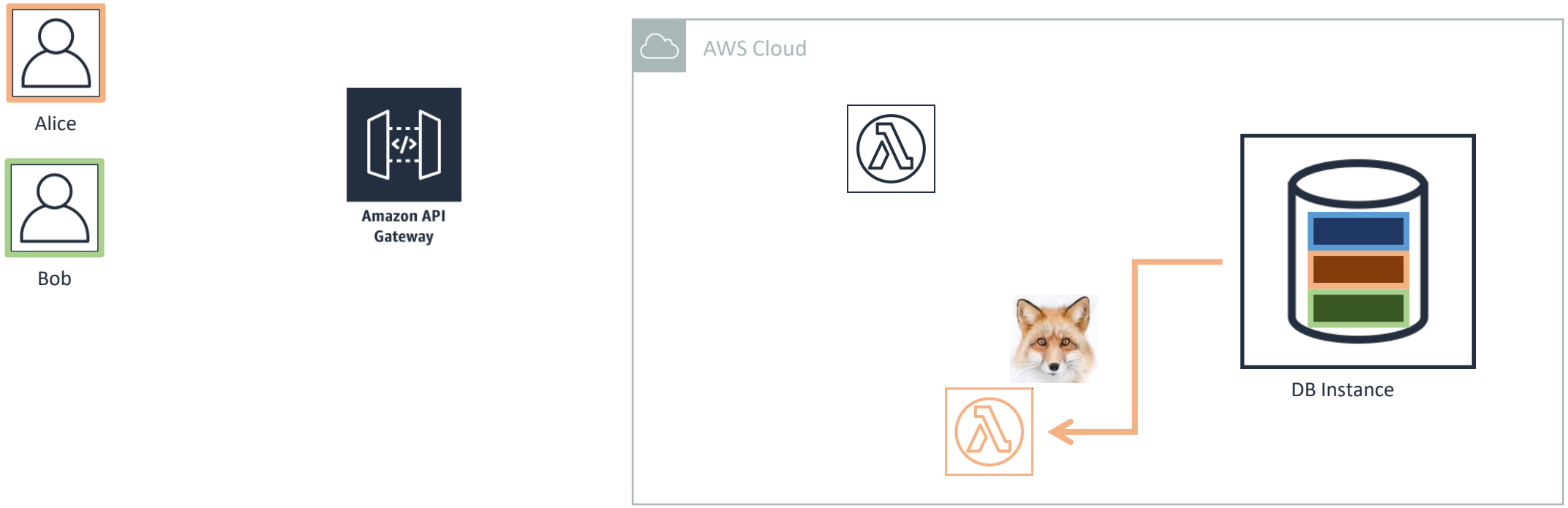
Serverless+IFC

Functions interact with DB



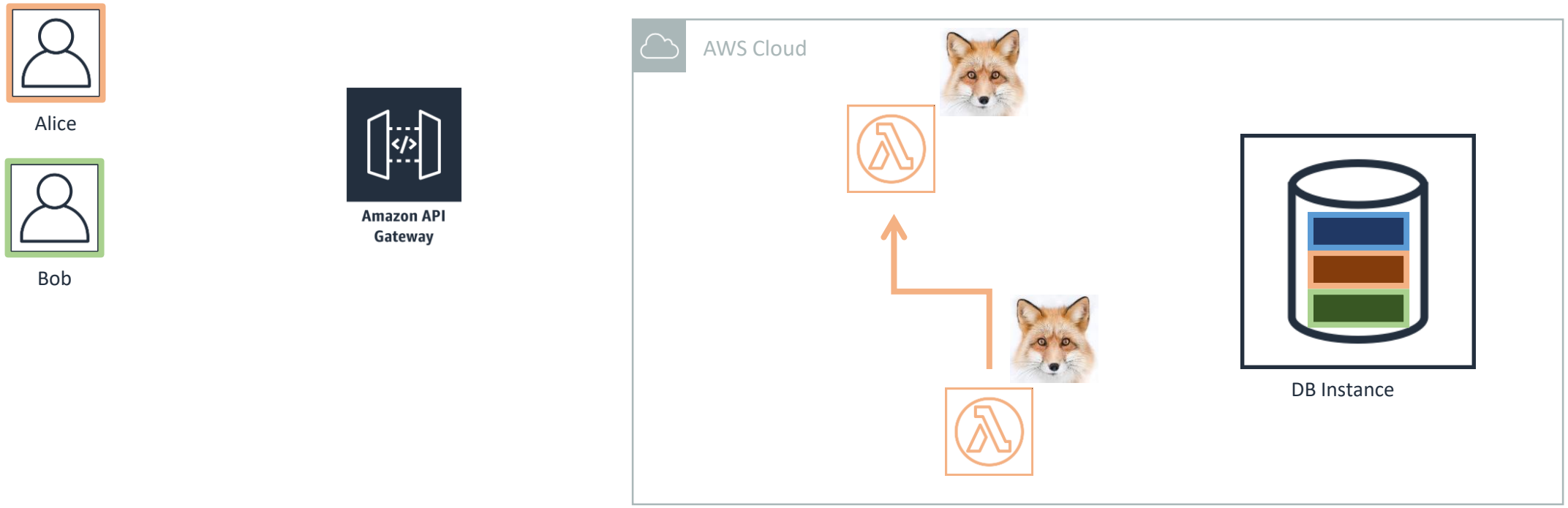
Serverless+IFC

Function reads **labeled** data and is marked with the **label**



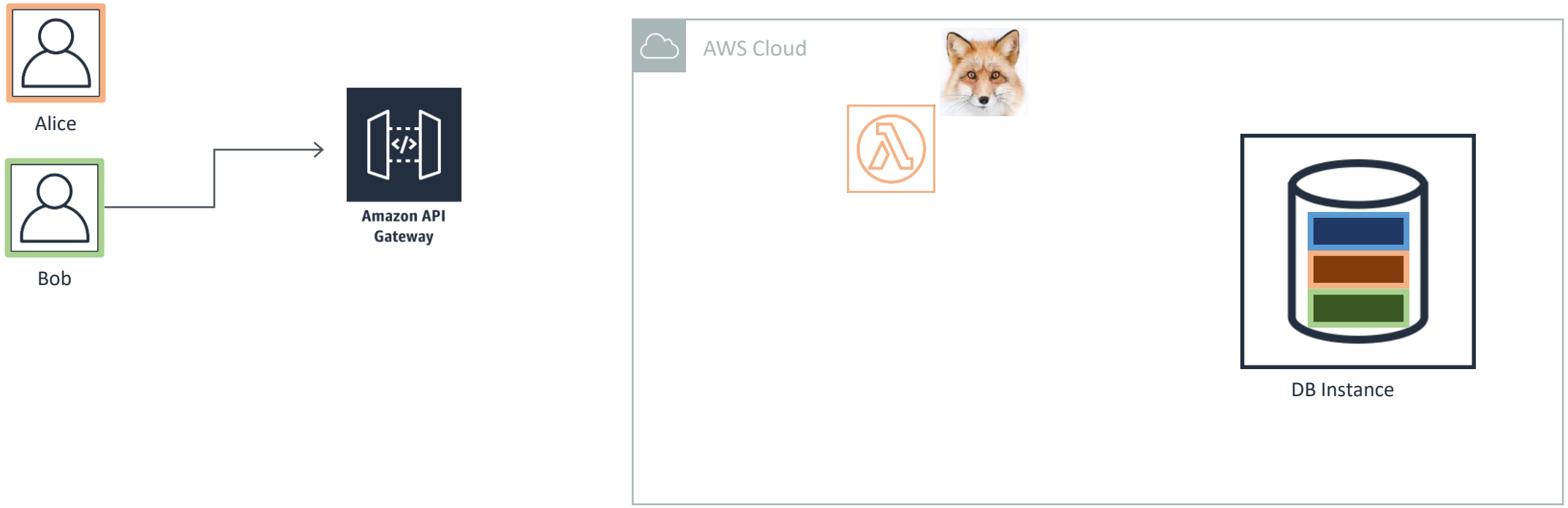
Serverless+IFC

Label is propagated across function calls



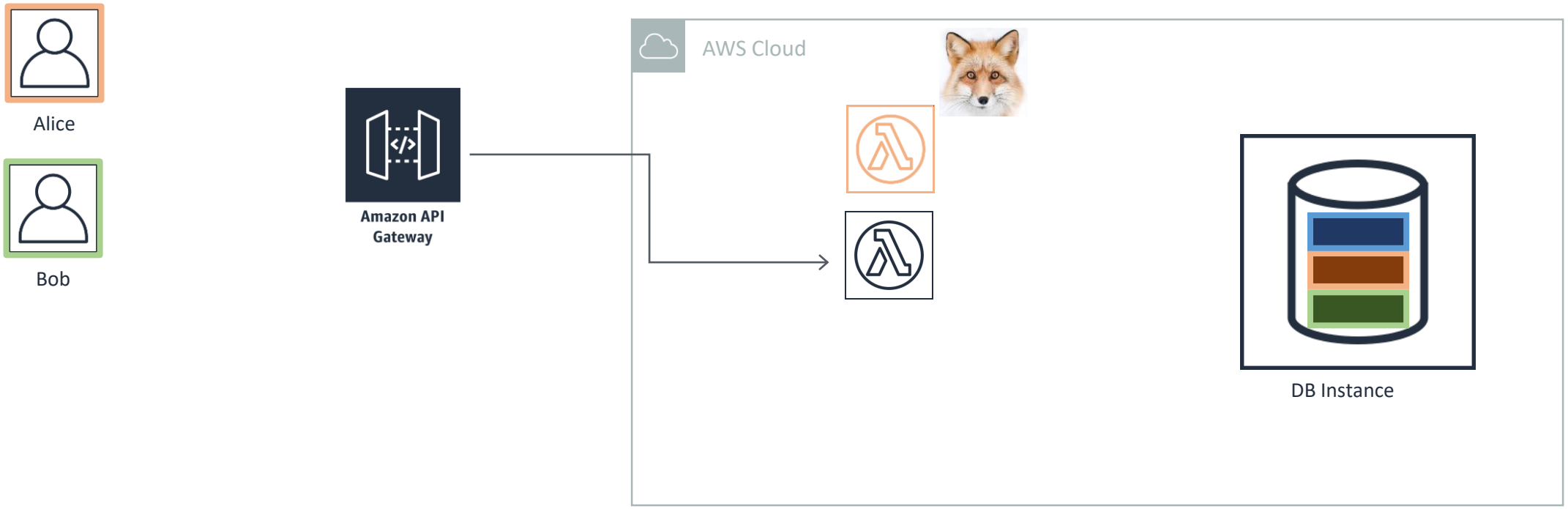
Serverless+IFC

Other requests may occur in parallel

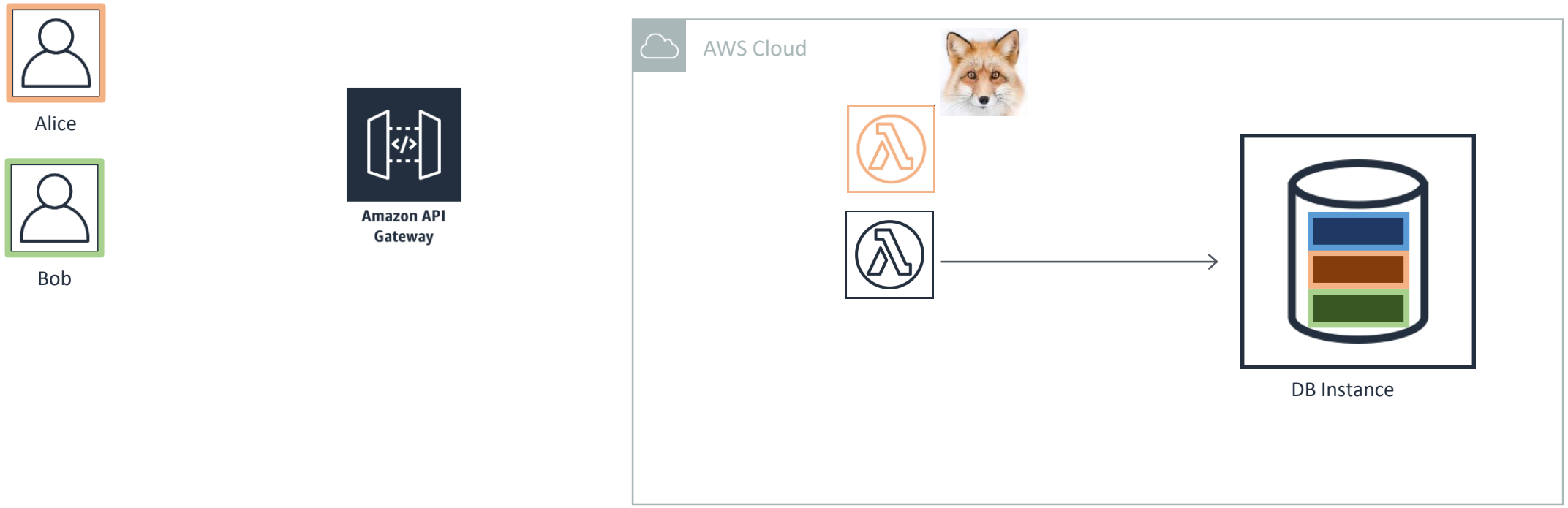


Serverless+IFC

Parallel requests spawn new functions, that are independent from one another



Serverless+IFC



Serverless+IFC

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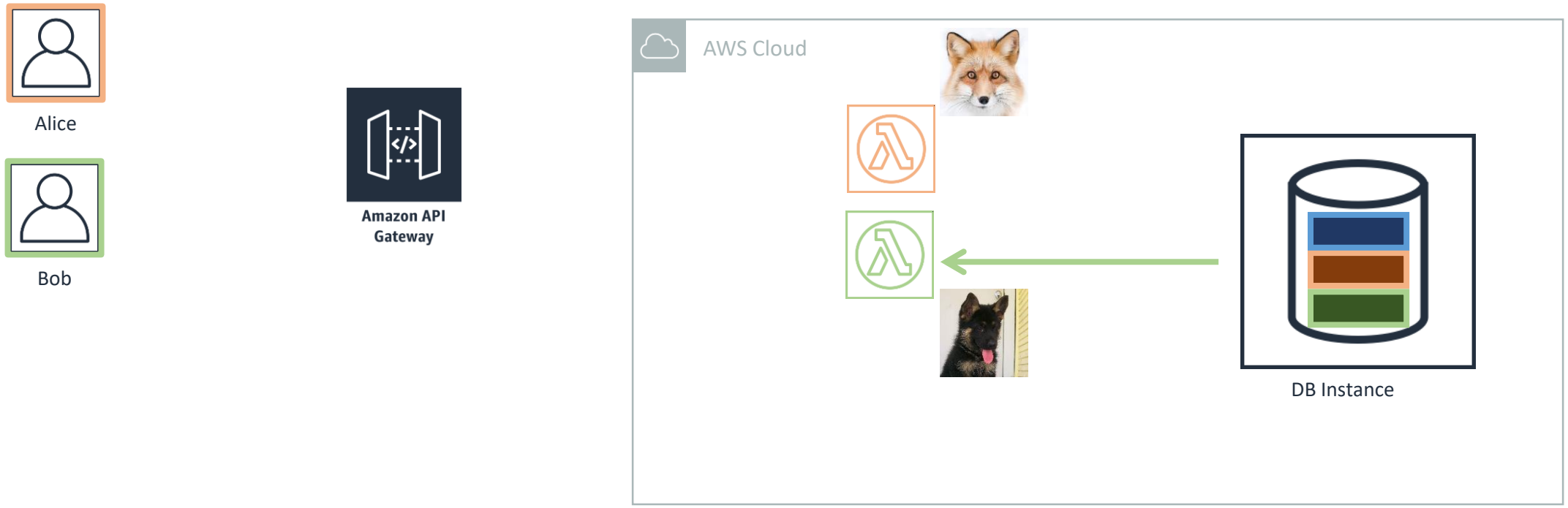
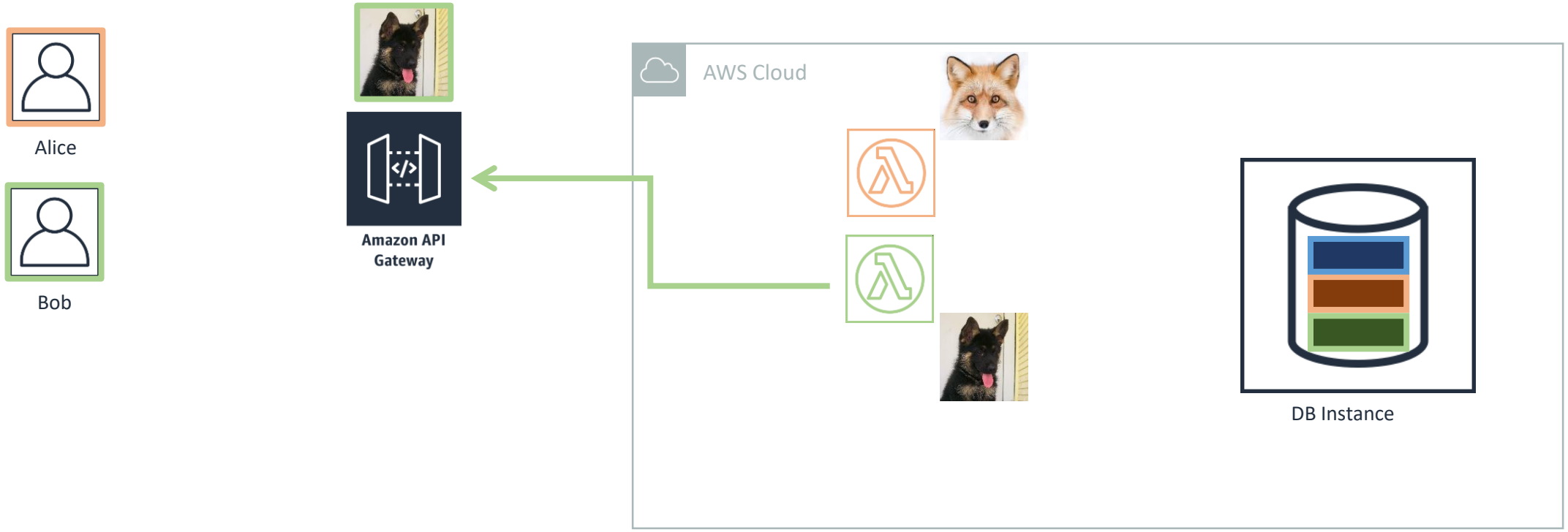


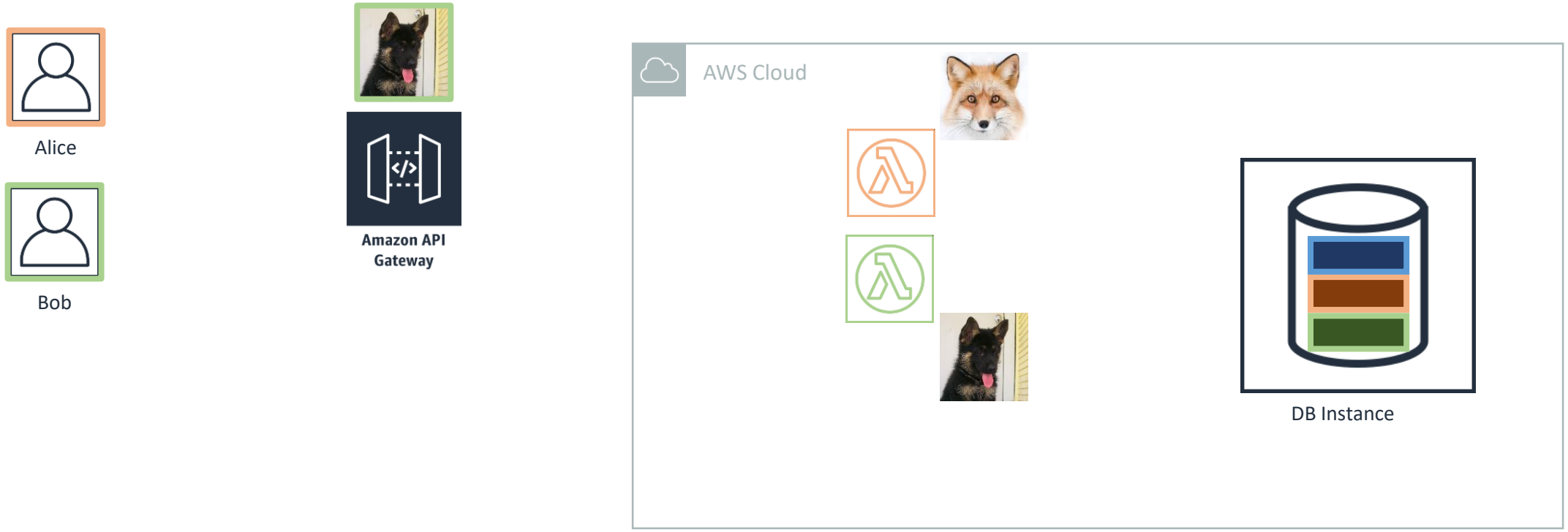
Serverless+IFC

Function returns result



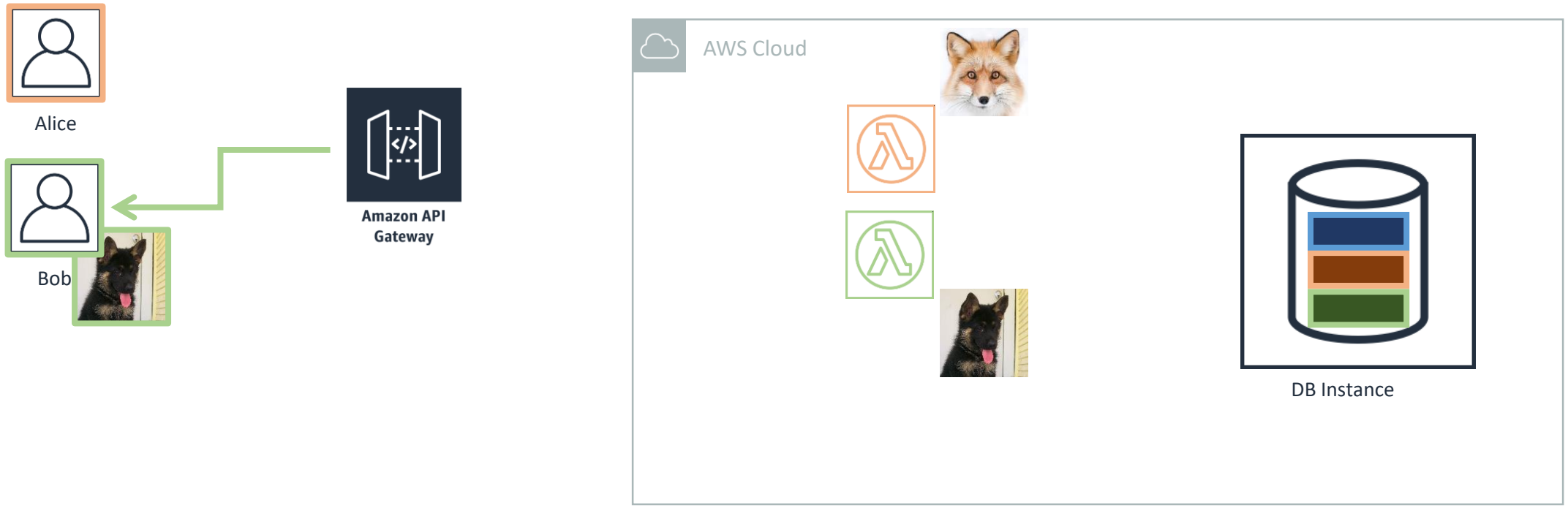
Serverless+IFC

Before the result is sent to the user, we can check that the security policy is not violated



Serverless+IFC

And send the response if it does not violate the security policy



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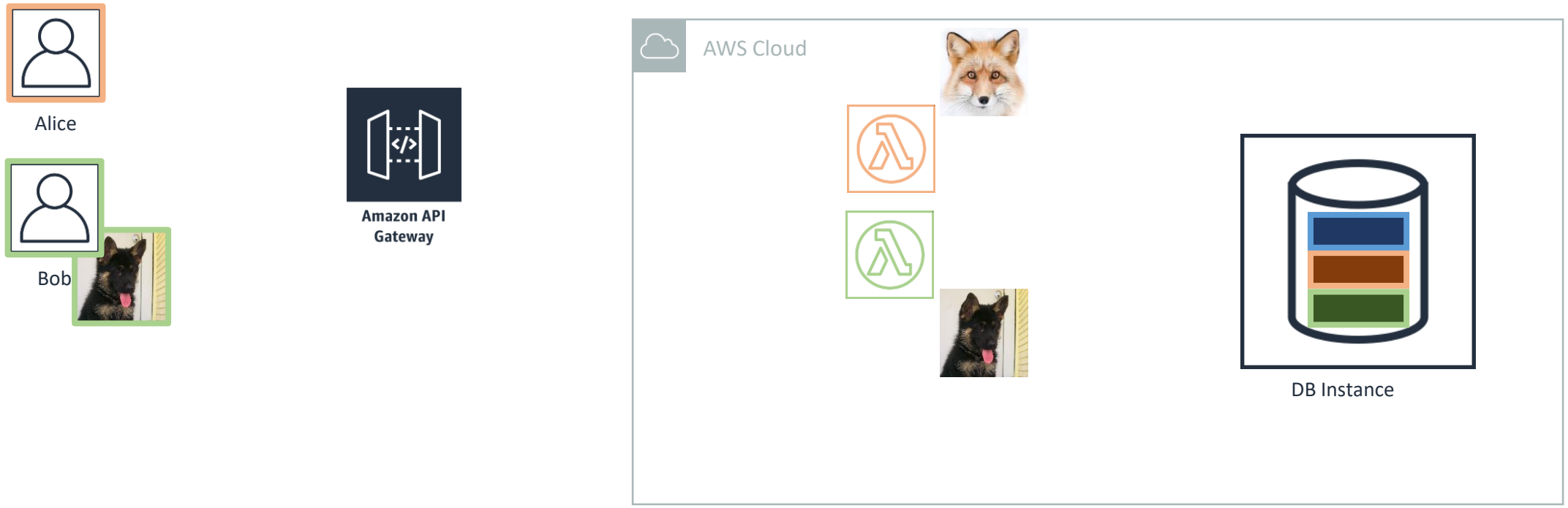

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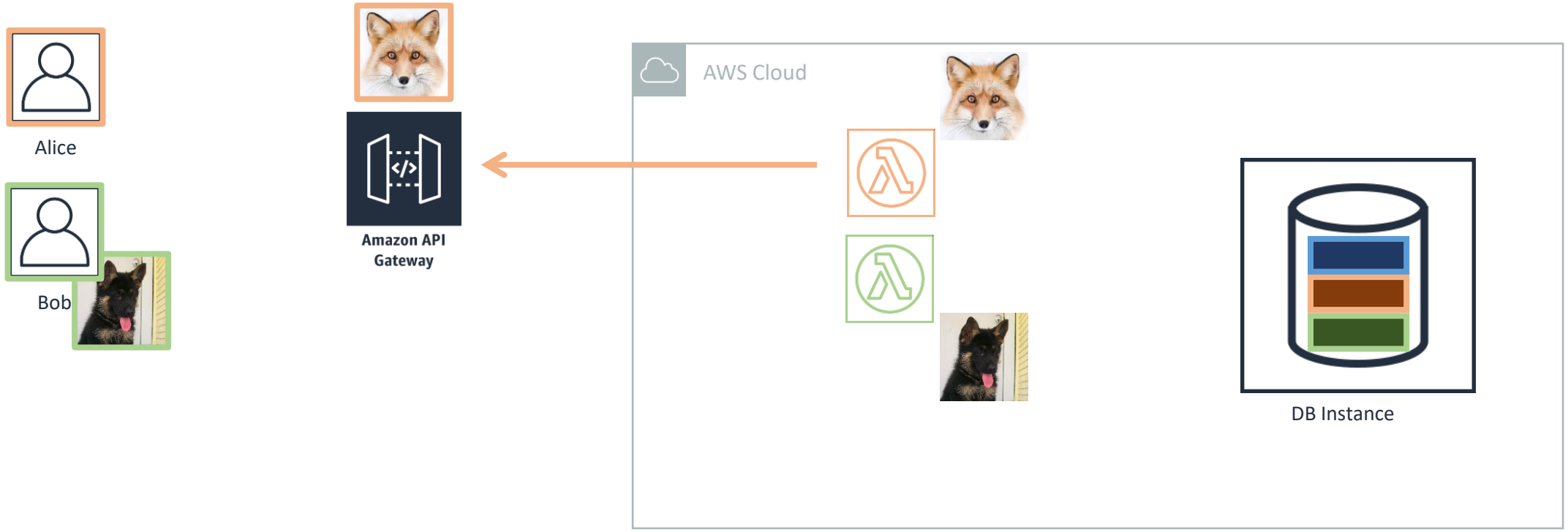

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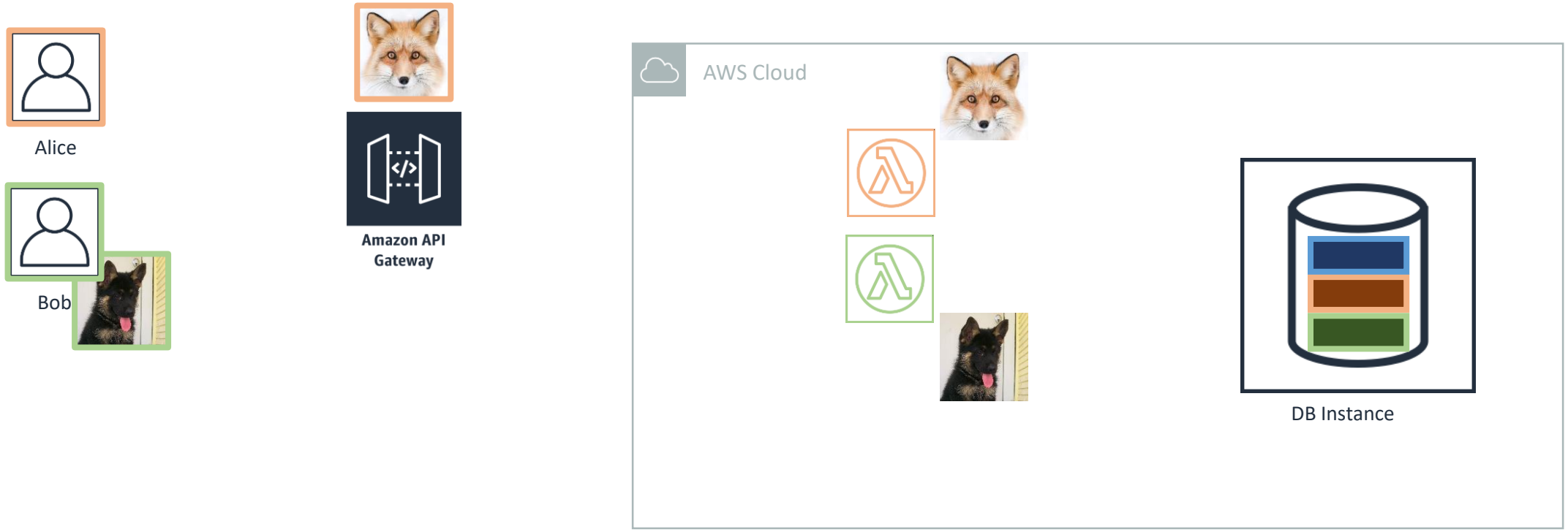

Serverless+IFC

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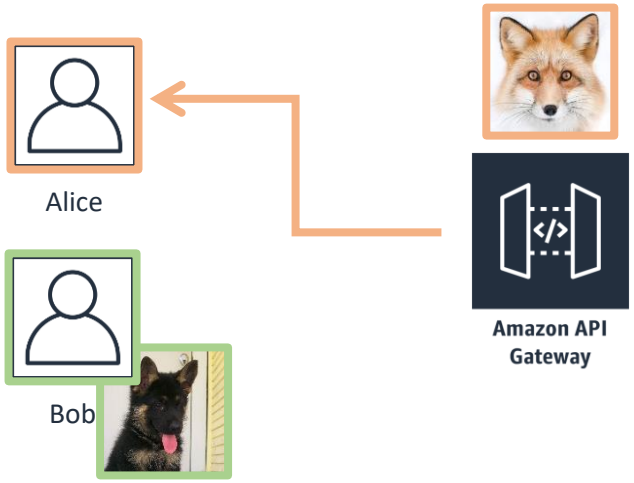

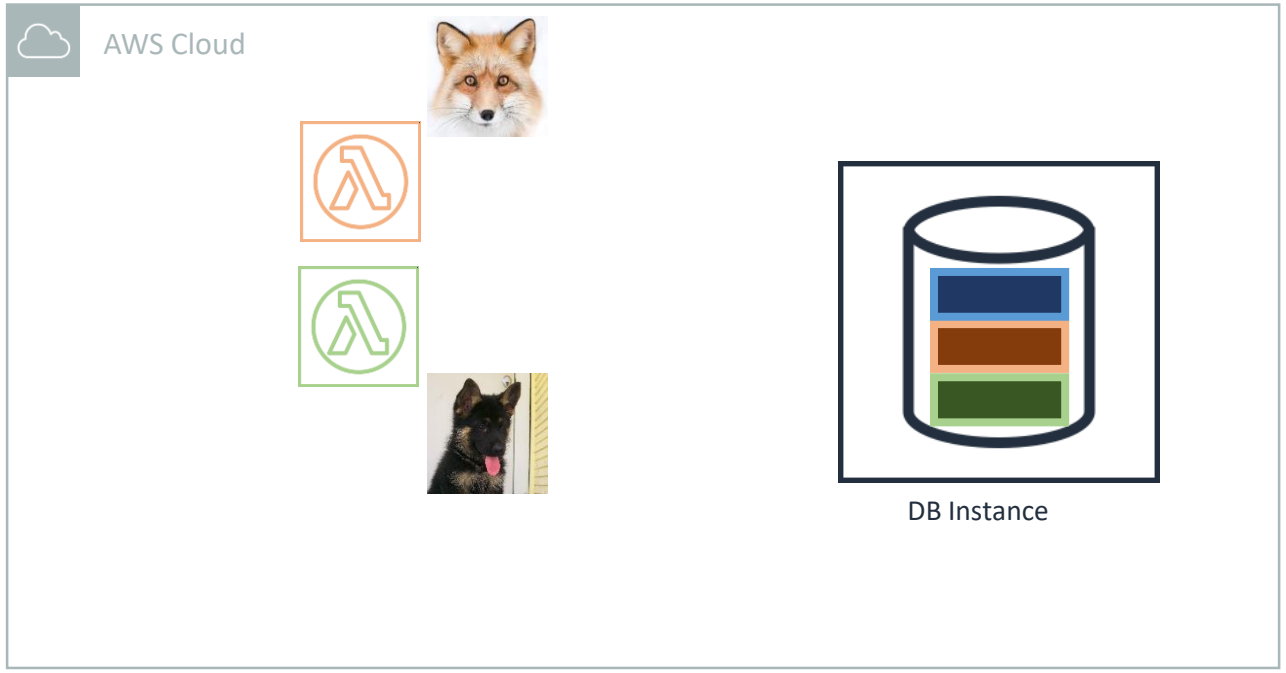

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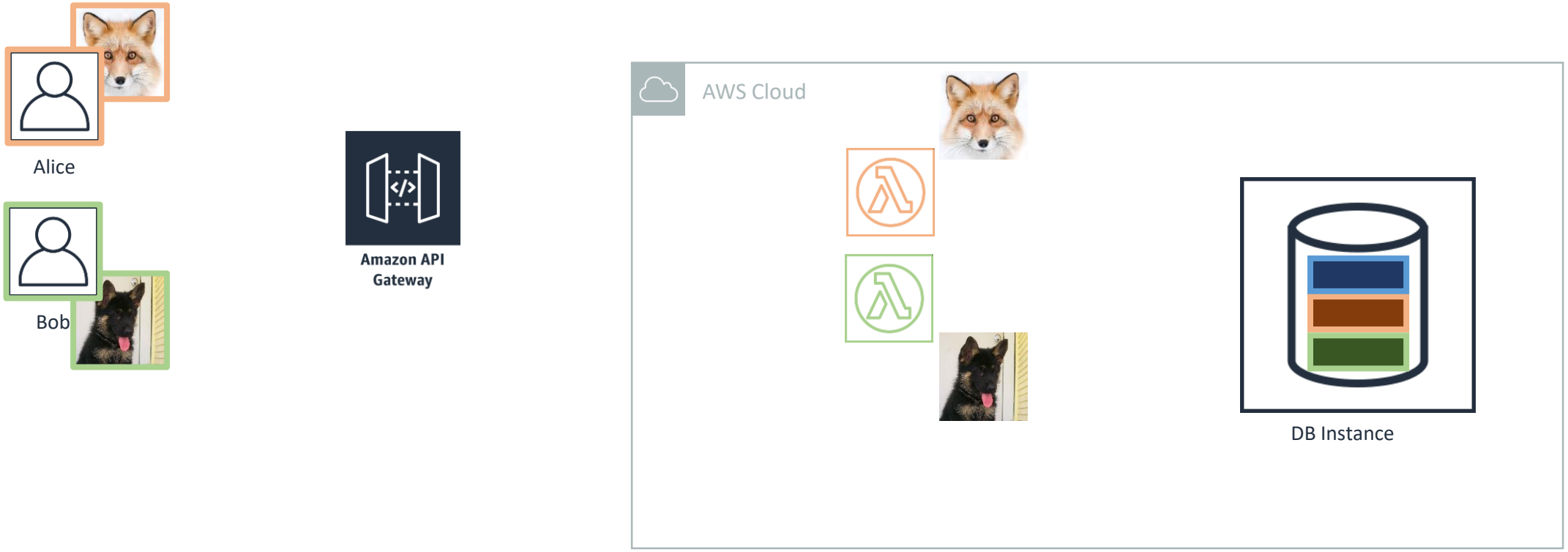
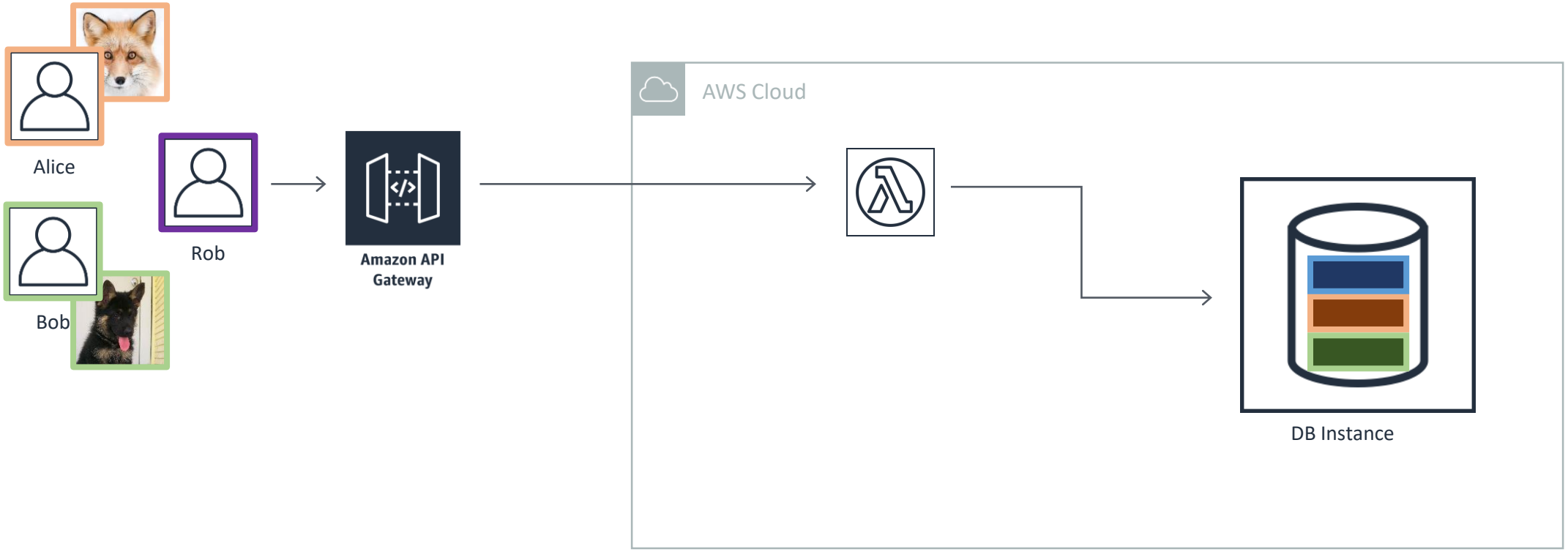


Serverless+IFC

Security policy might have a hierarchy – making shared dbs unavoidable



Serverless+IFC

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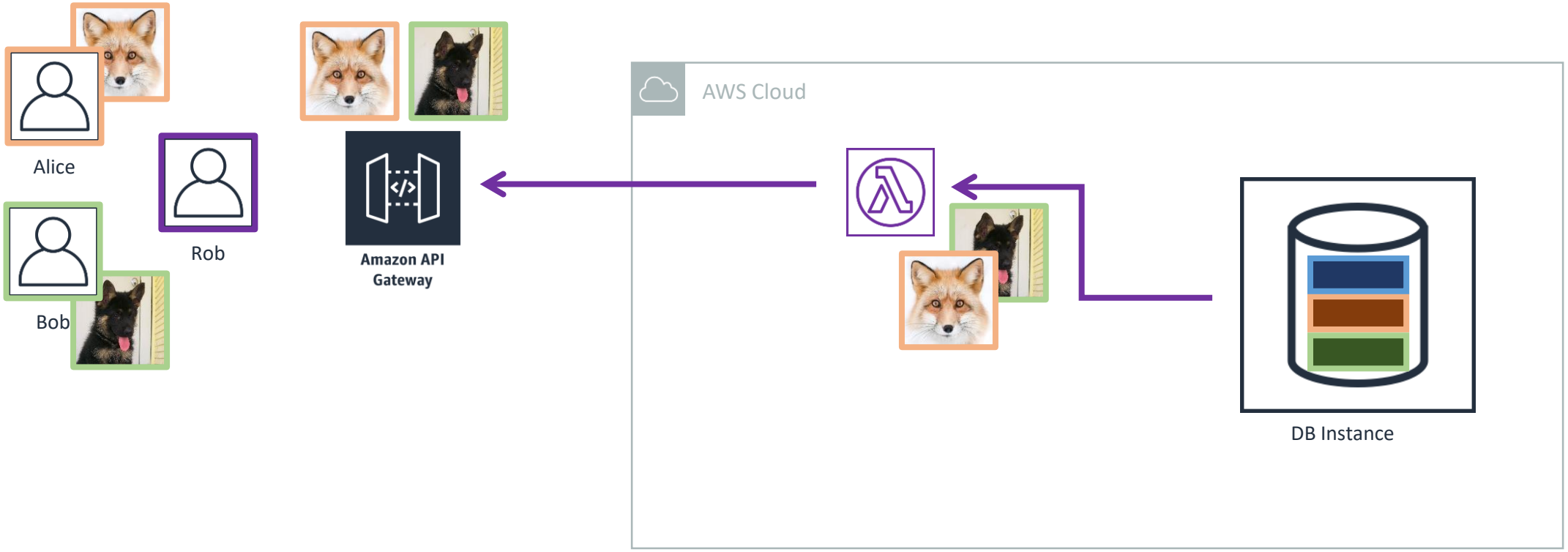

Serverless+IFC

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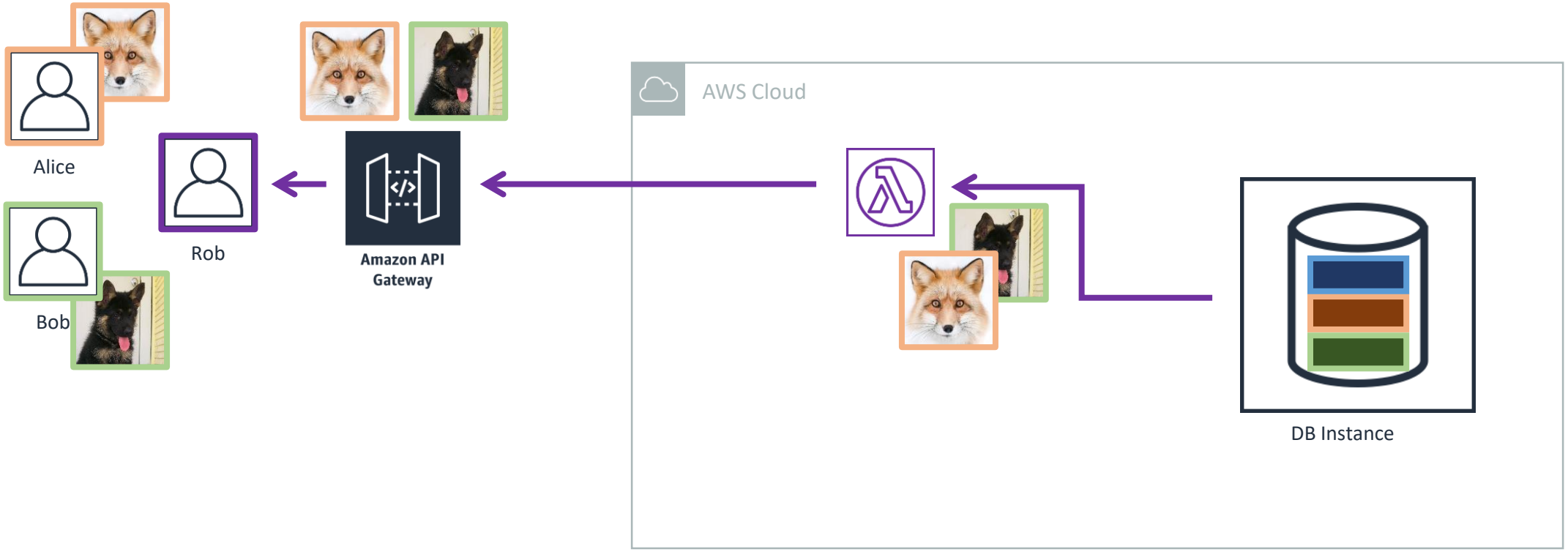
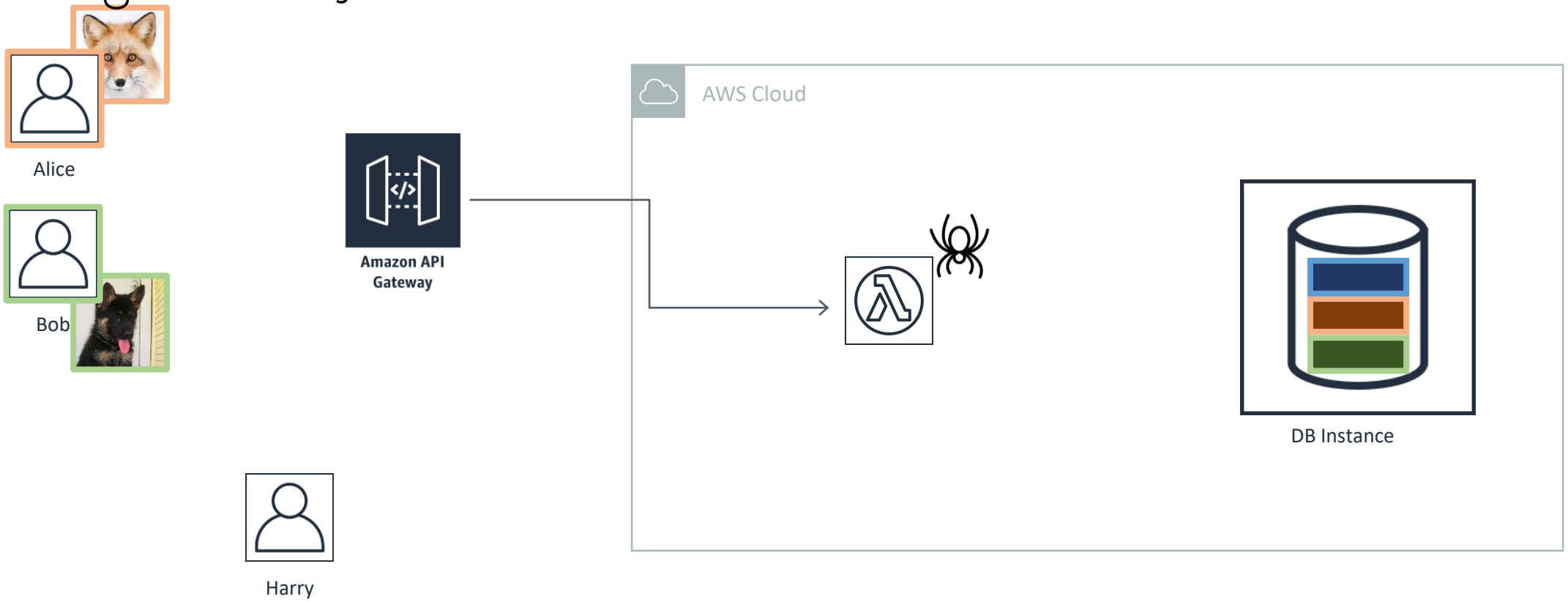


Serverless+IFC

What happens when a hacker tries to steal data?

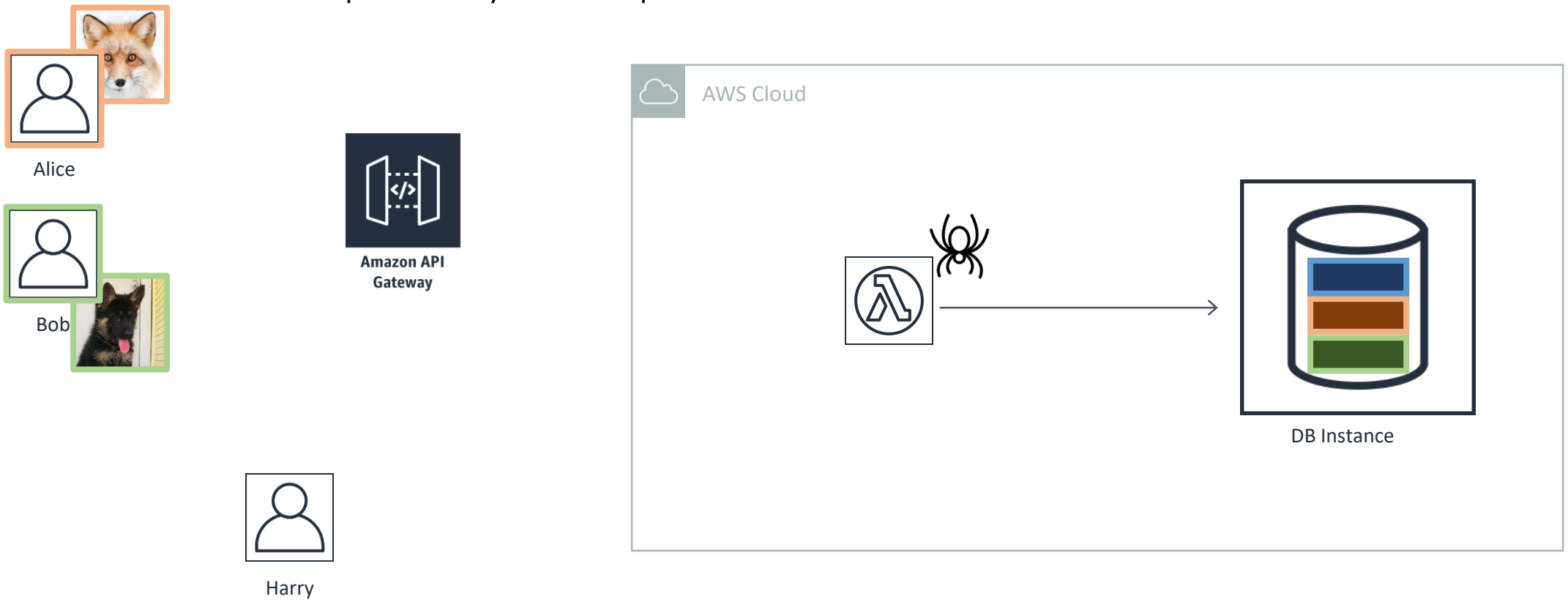
Serverless+IFC

The hacker might exploit some vulnerability in the application (e.g. code injection)



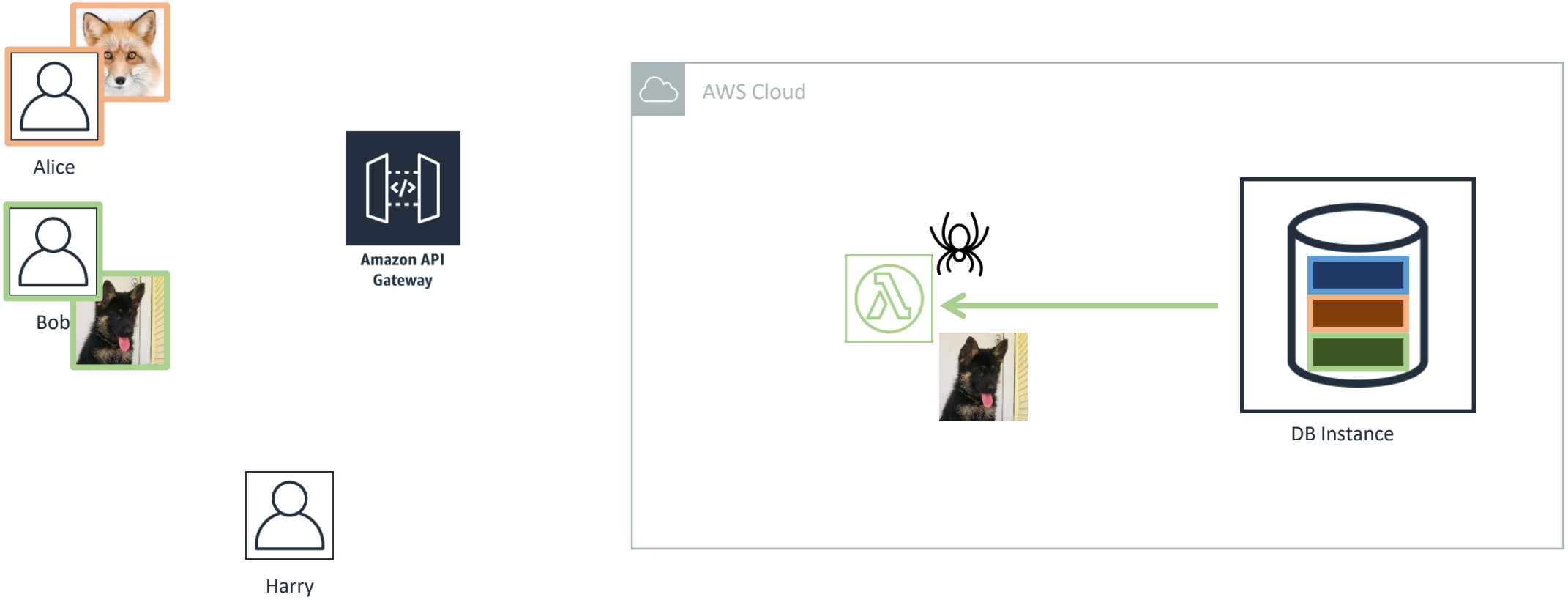
Serverless+IFC

Trapeze guarantees security even if the underlying function code is completely compromised



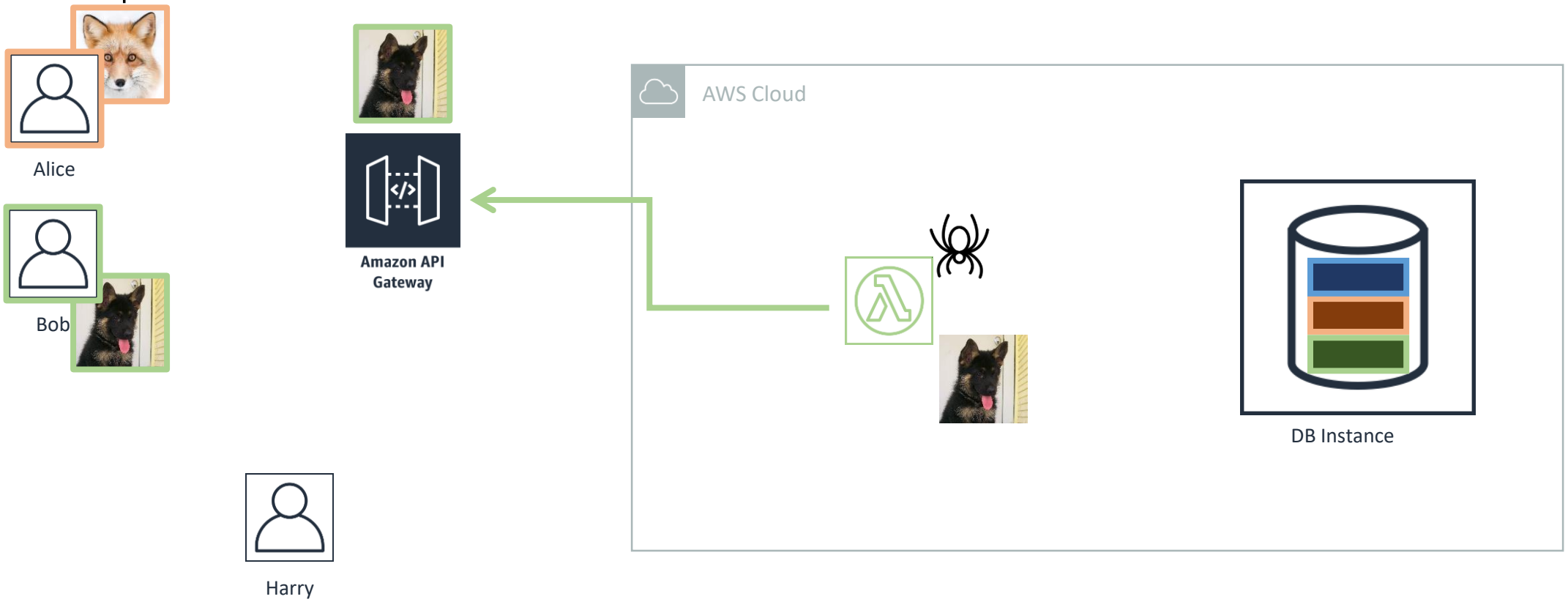
Serverless+IFC

The malicious code may read a secret, and is marked with a **label**



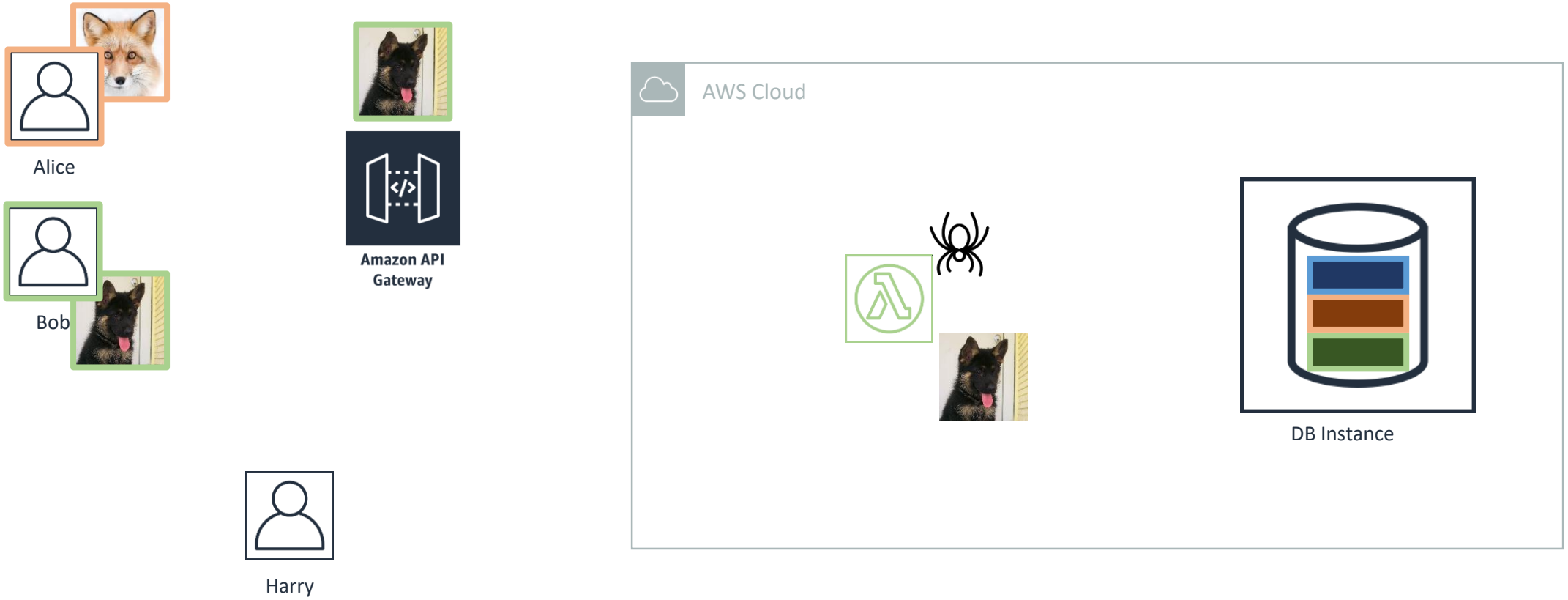
Serverless+IFC

The malicious function then tries to send the secret in a response



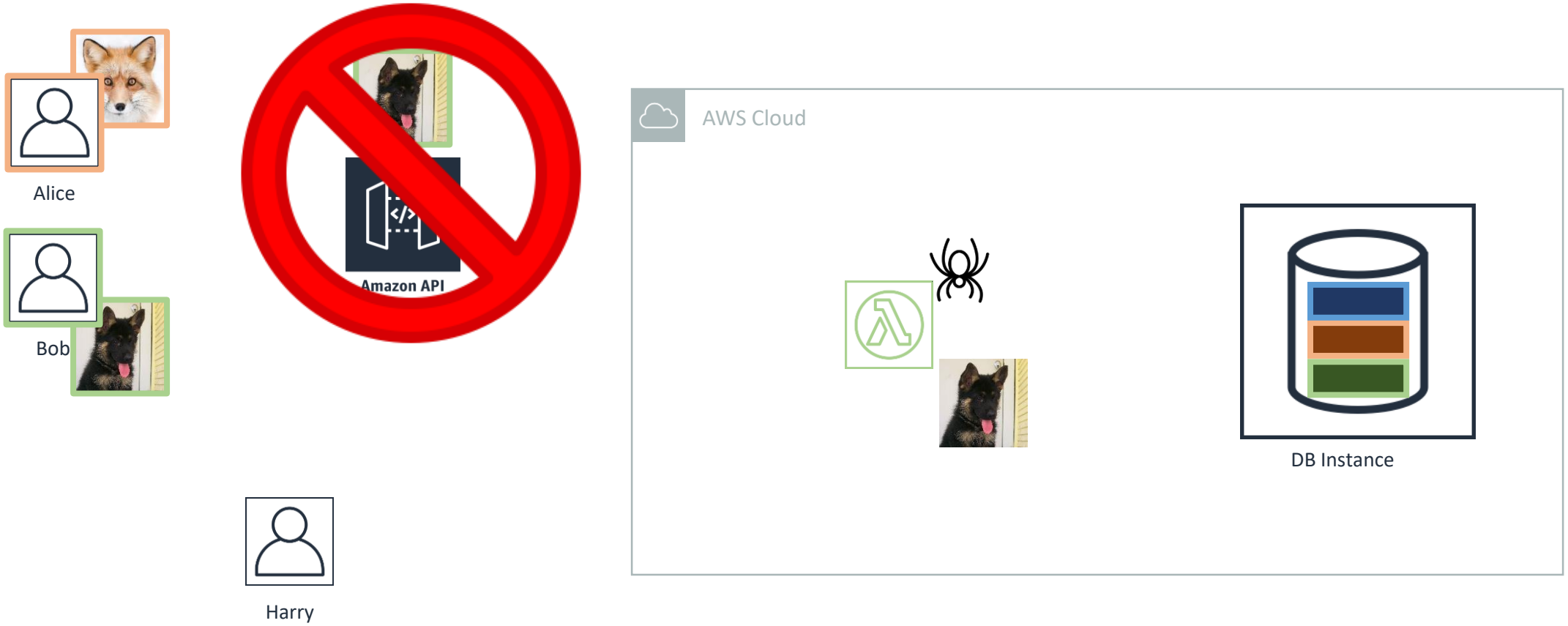
Serverless+IFC

At which point we can check if the hacker is allowed to see the data



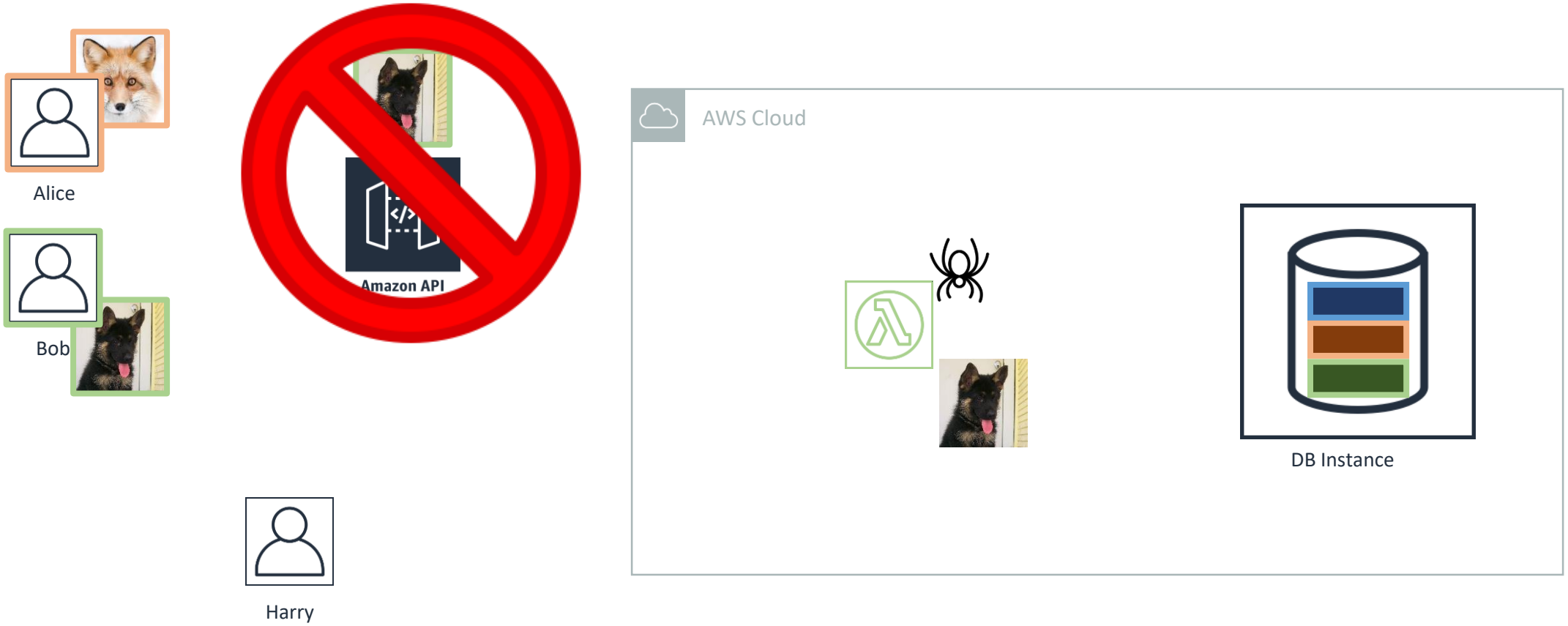
Serverless+IFC

And block the request from being sent



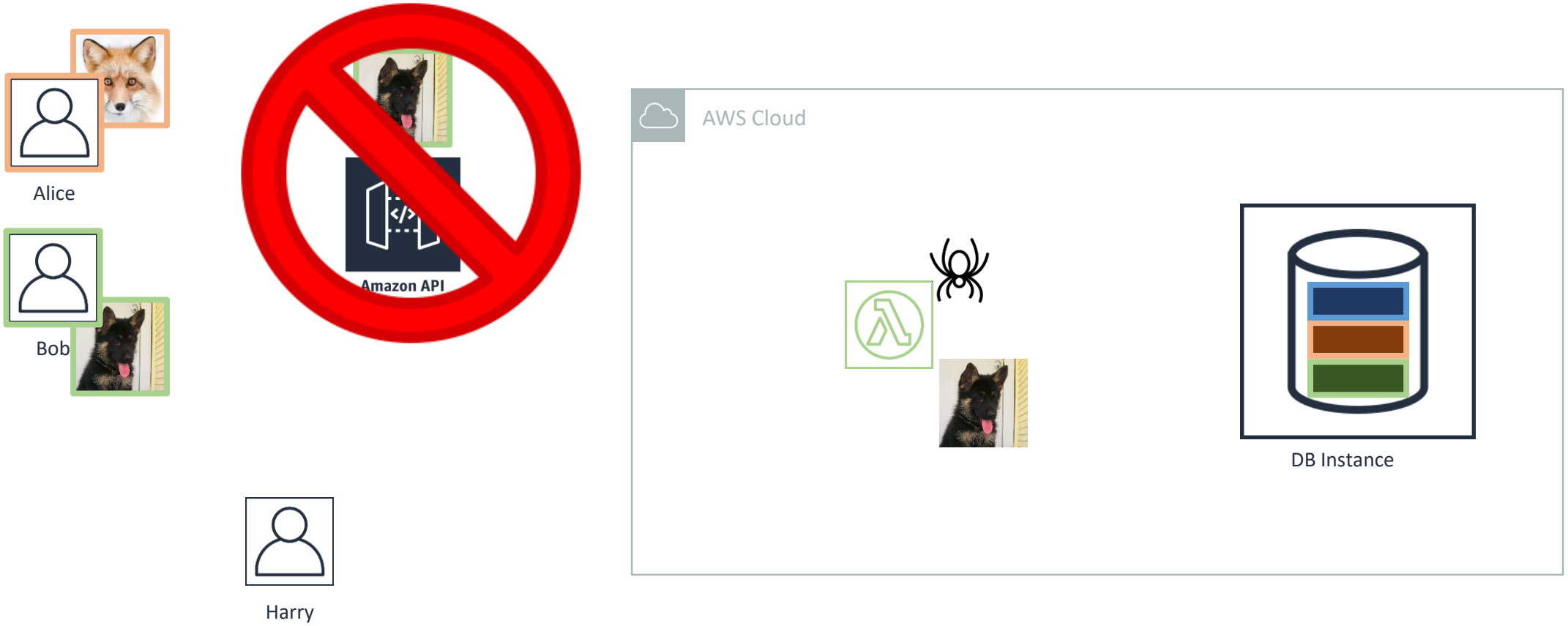
Termination Channel

But – the attacker learned of the existence of secret data



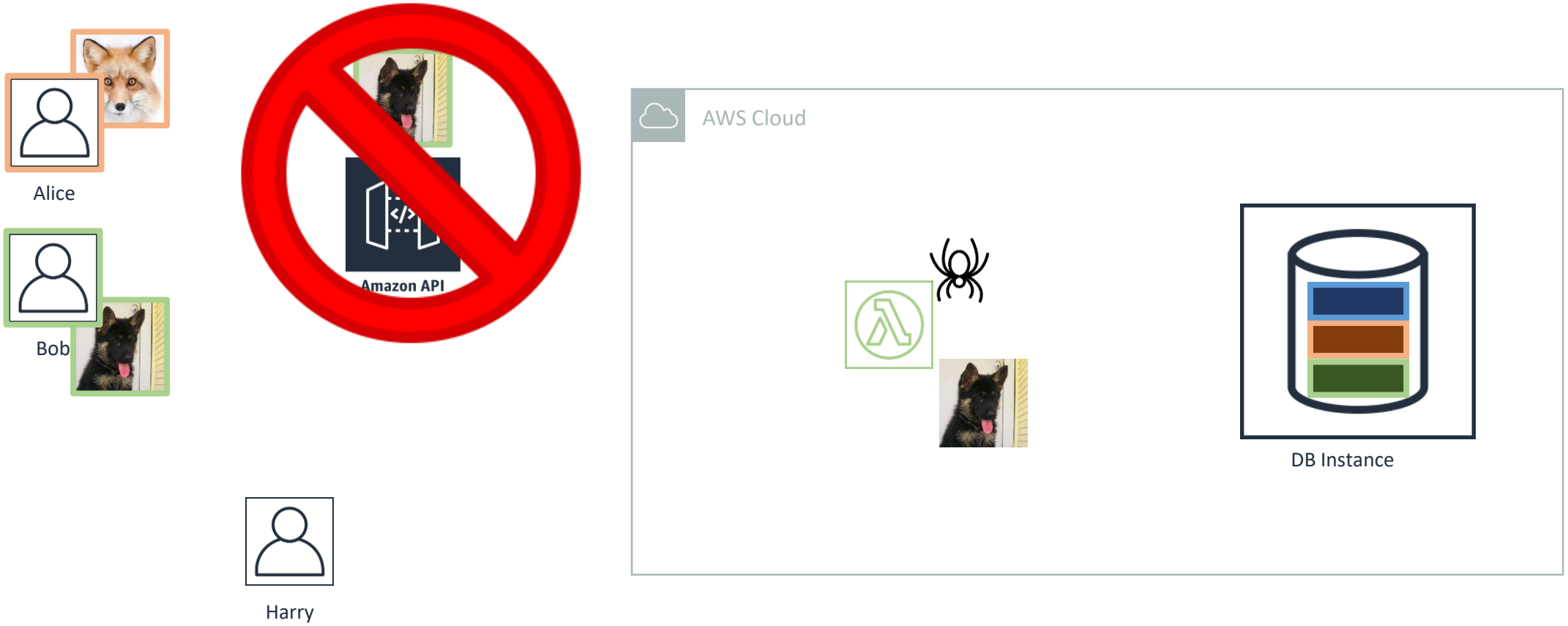
Termination Channel

Which is bad if **the existence of a secret is itself a secret**



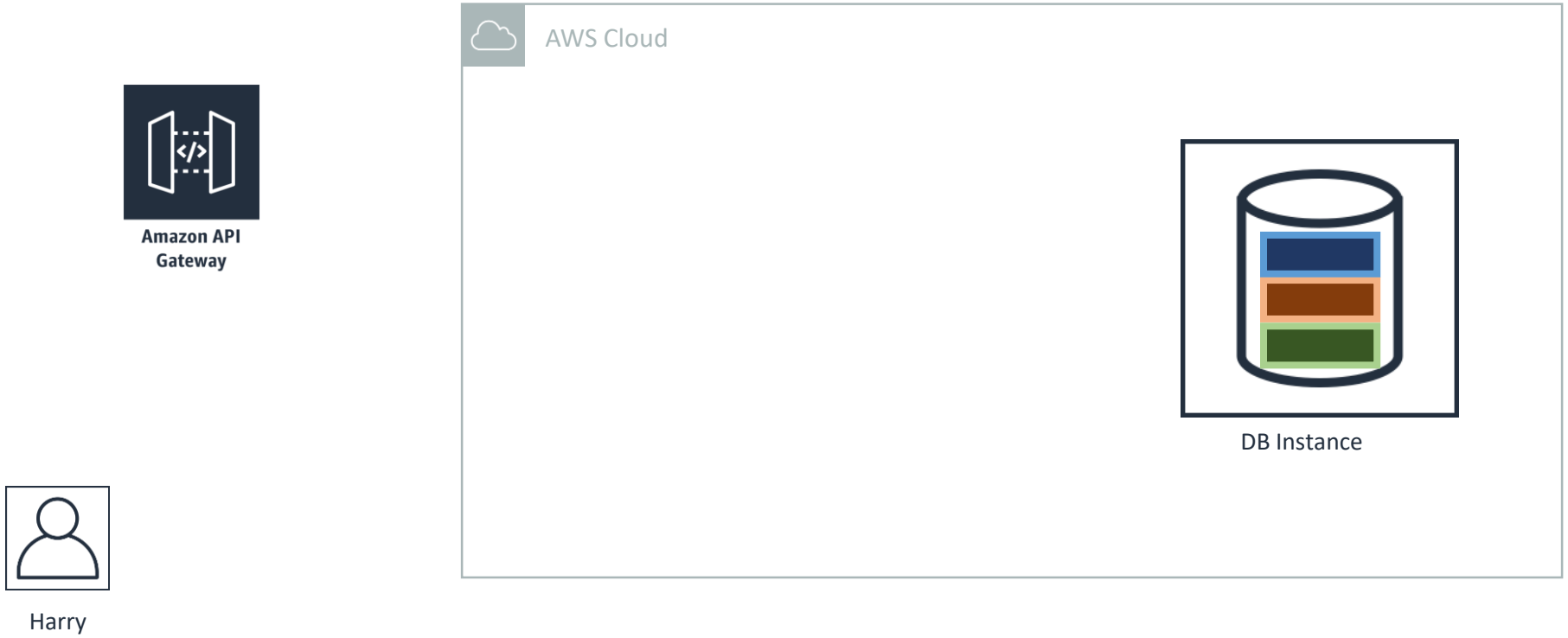
Termination Channel

Termination Insensitive Non-Interference is insufficient!



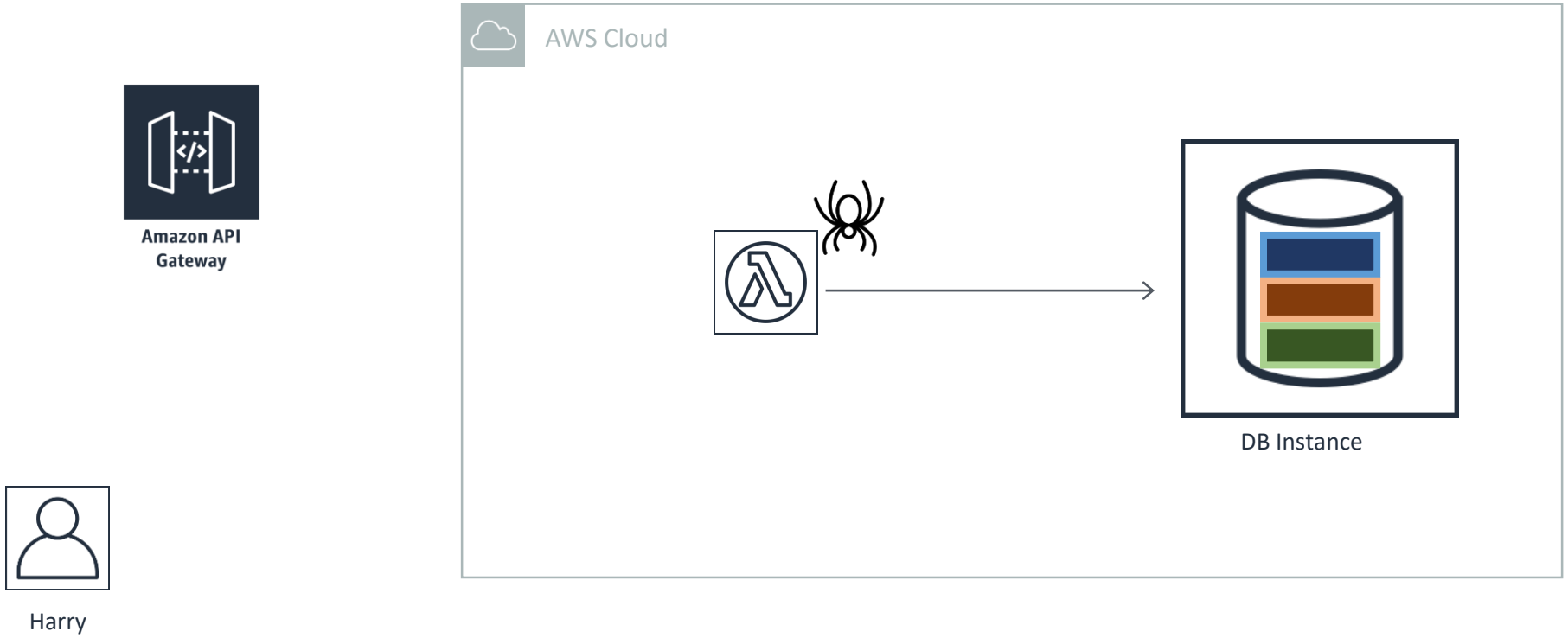
Termination Channel

Attacker can encode a secret value by making certain values 'inaccessible'



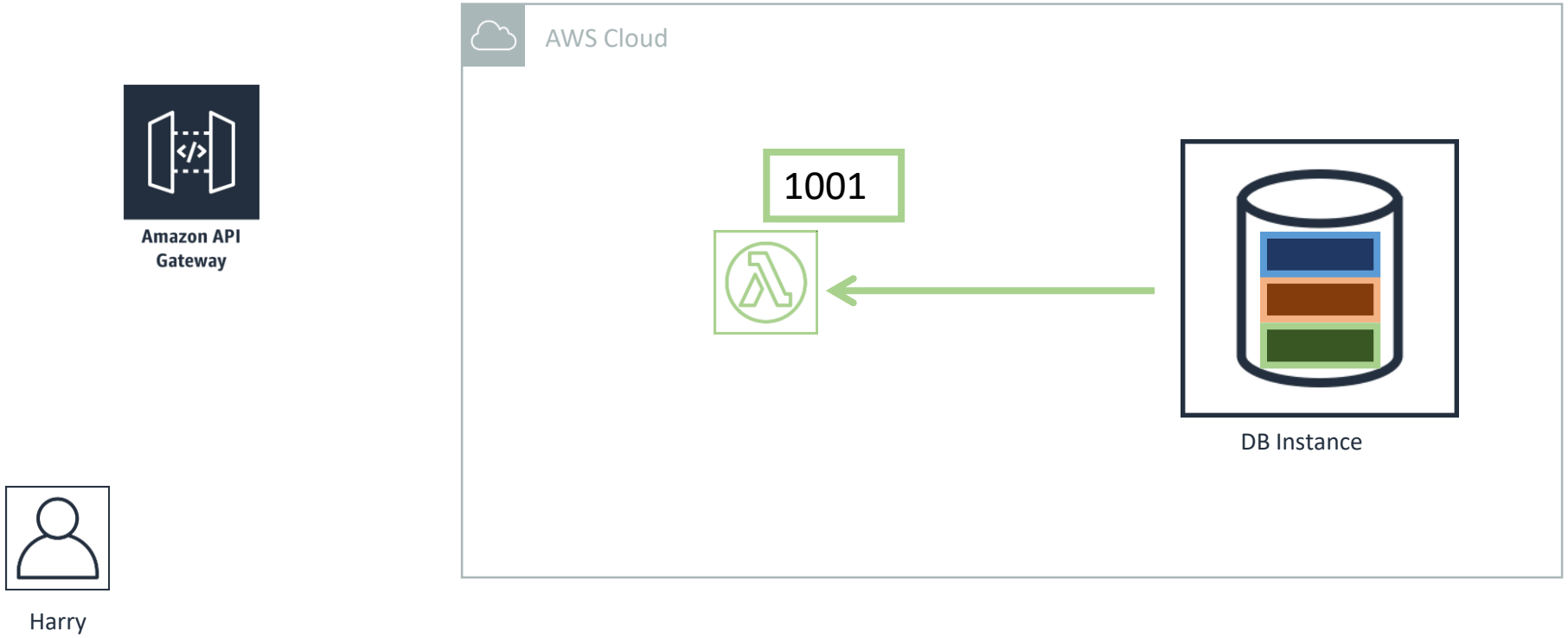
Termination Channel

Attacker reads a secret value



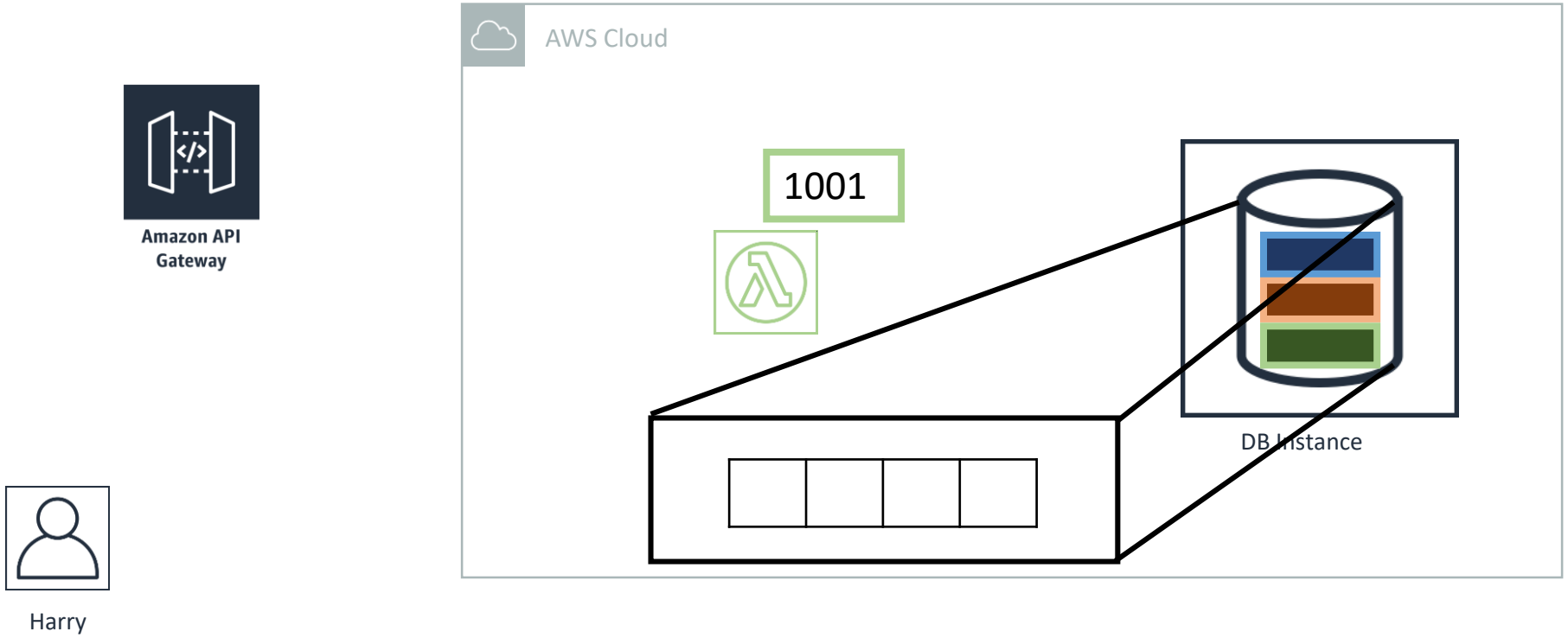
Termination Channel

Attacker reads a secret value ('1001')



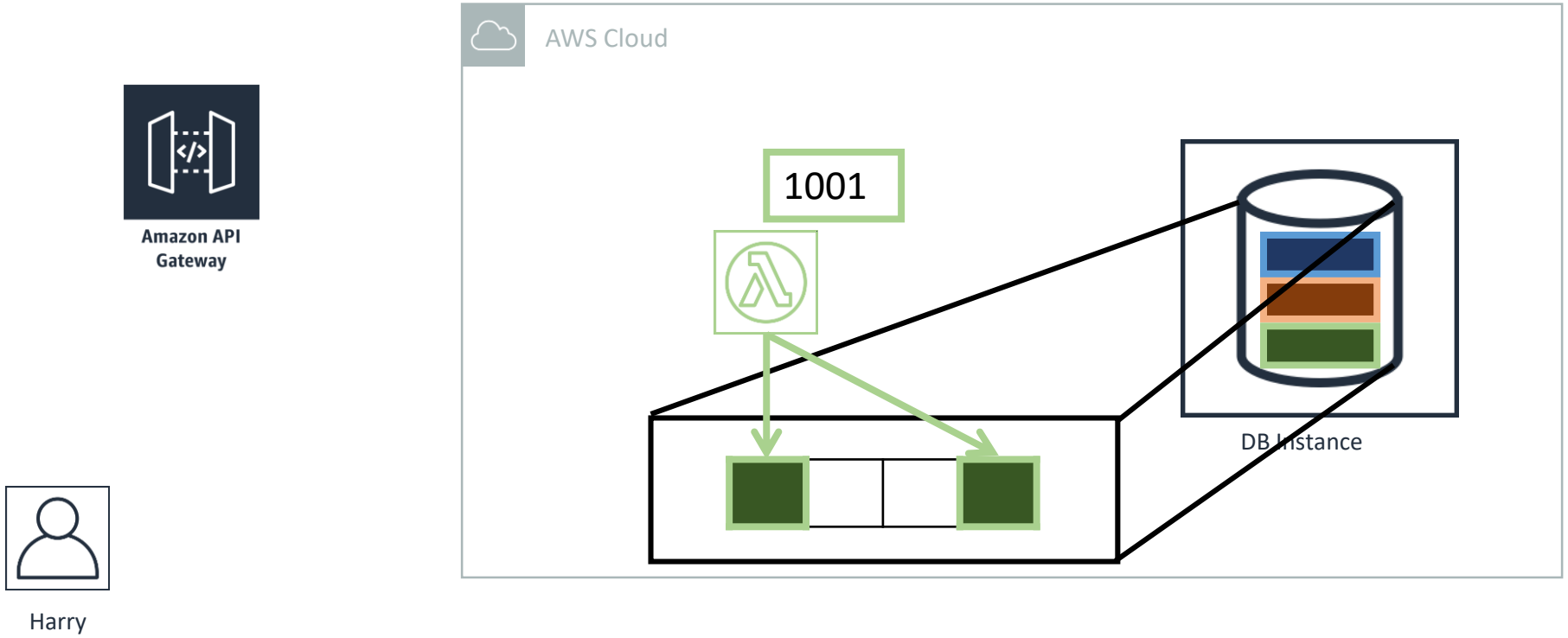
Termination Channel

Write something to predefined locations



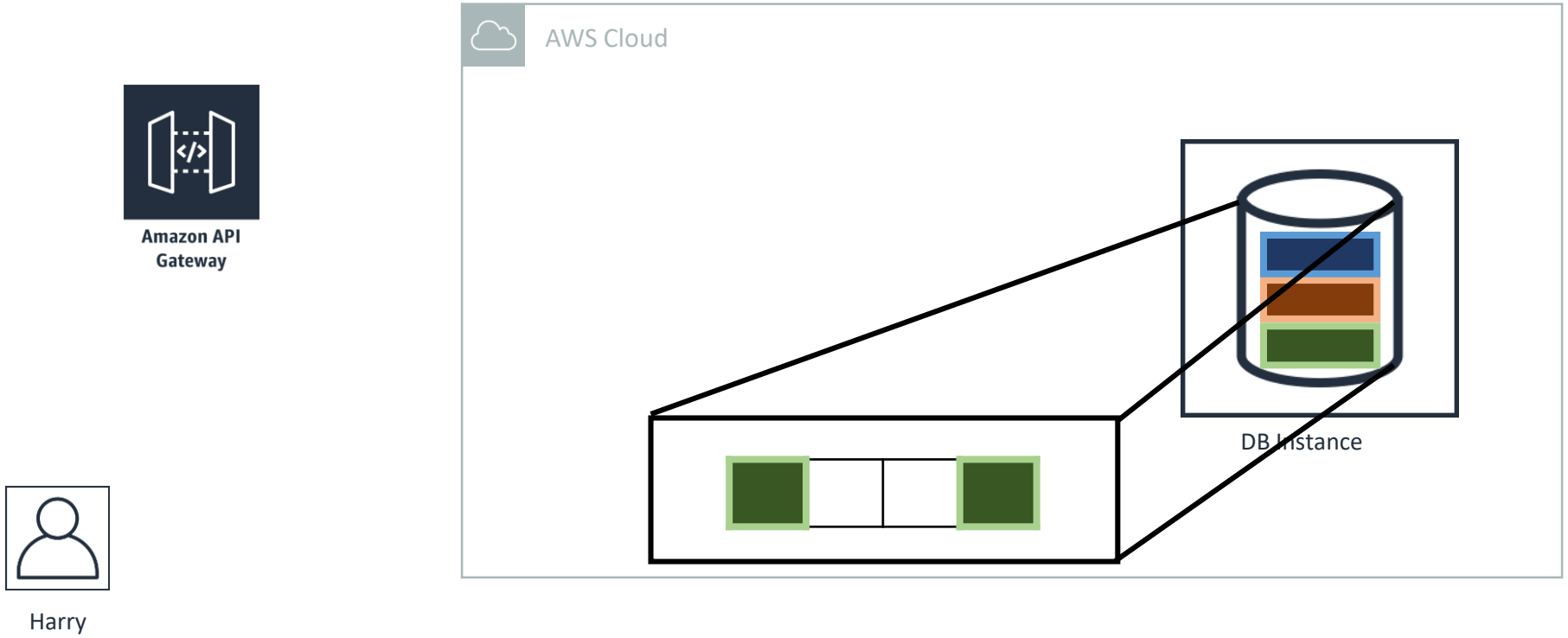
Termination Channel

Encode secret as a memory storage pattern



Termination Channel

Attacker can leak every bit by accessing each cell separately



Termination Channel

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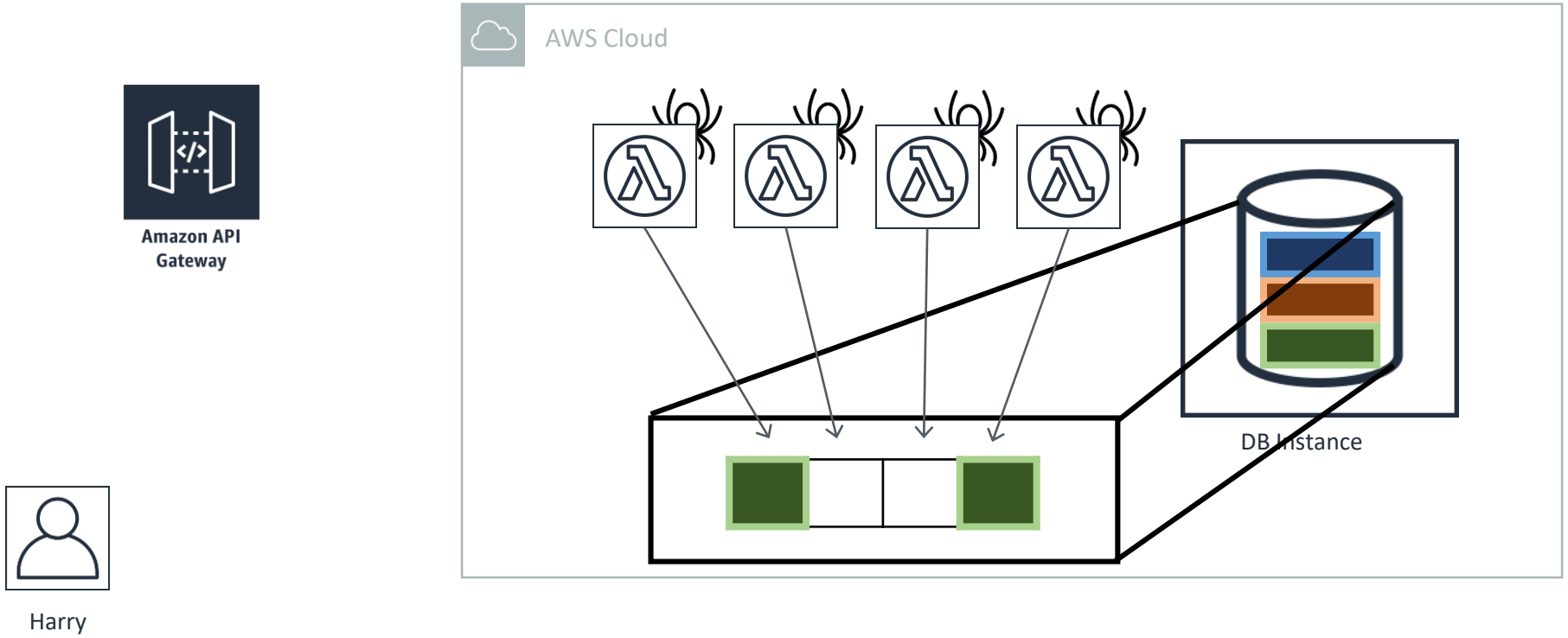

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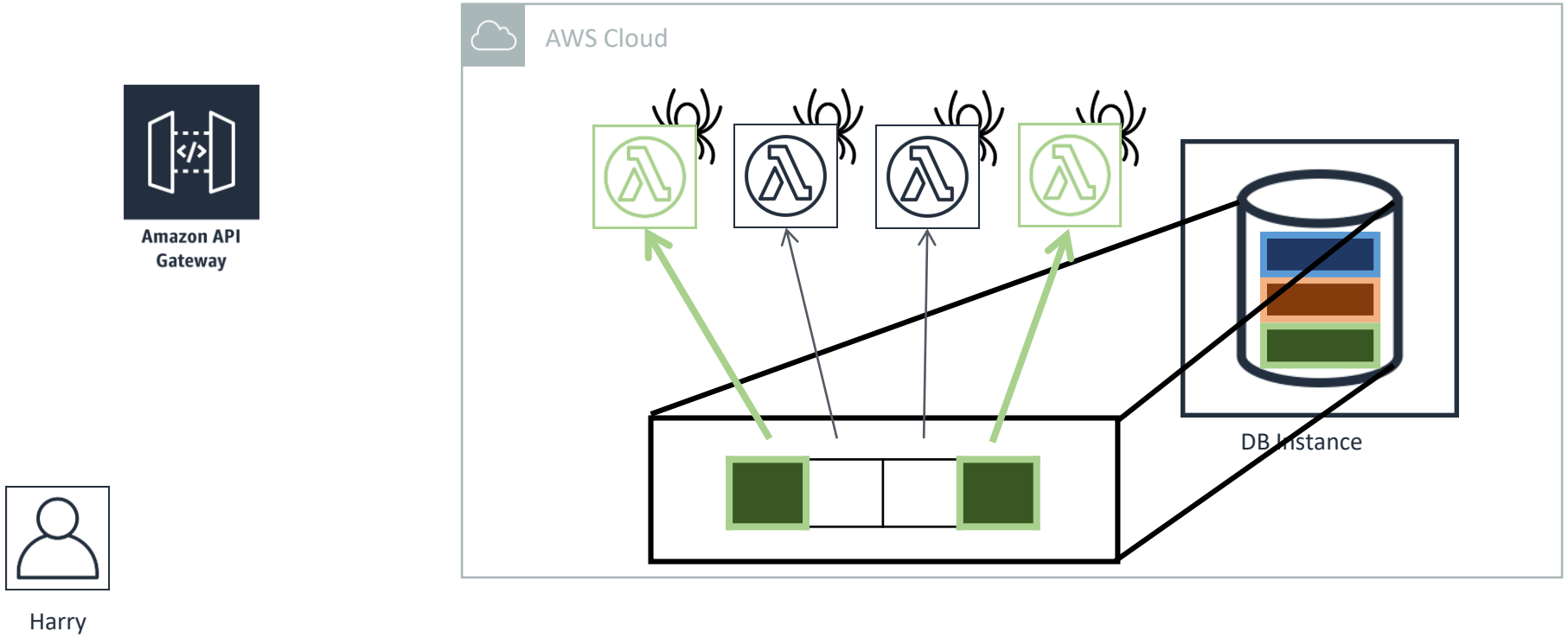
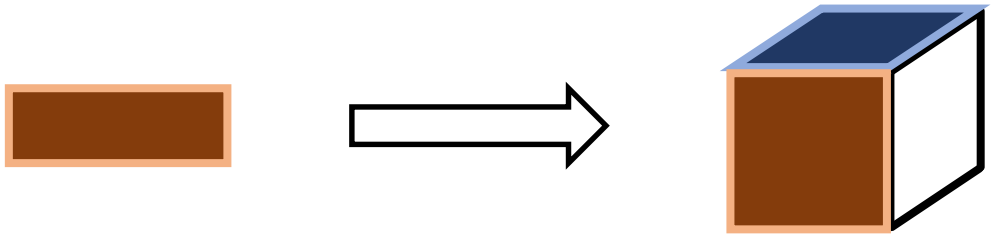


Closing the Termination Channel

How do we get *Termination* ***Sensitive*** *Non-Interference*?

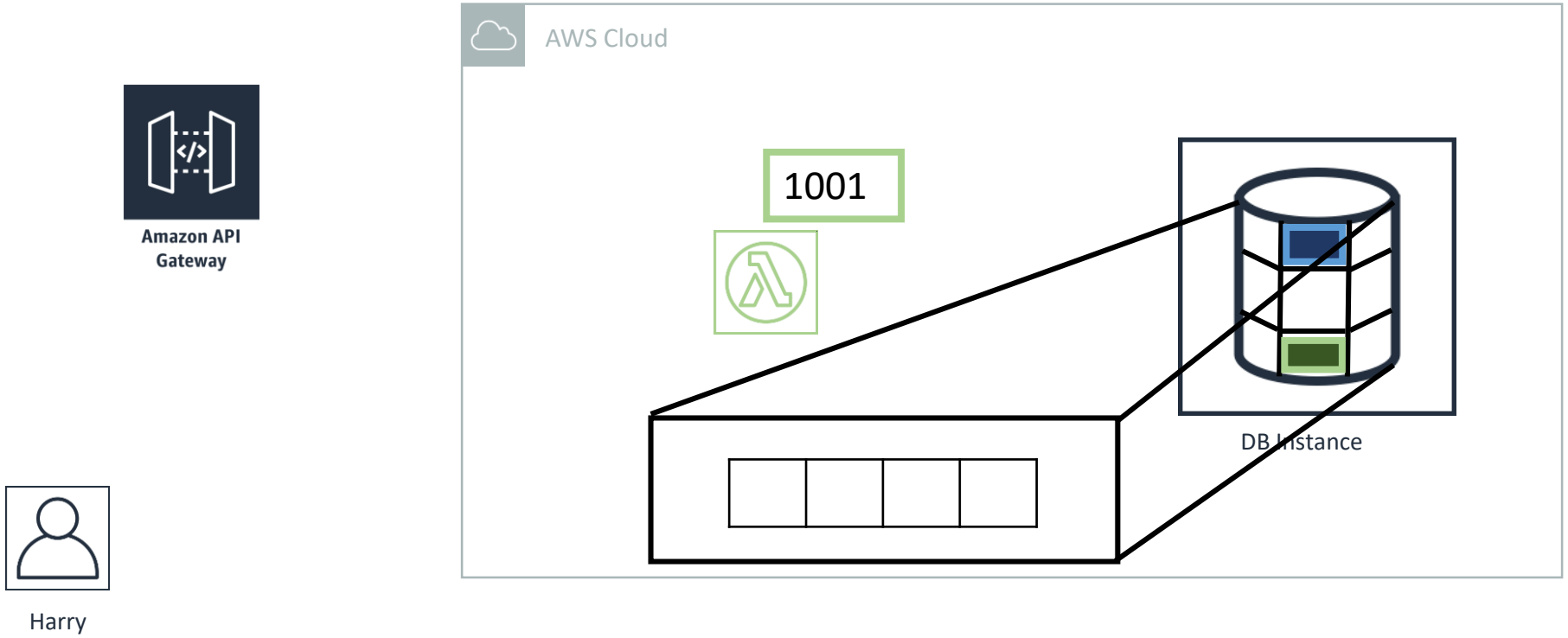
- Static labeling instead of floating labels
  - Label assigned at function invocation
  - Output behavior depends on invocation, not secret

- Faceted data store



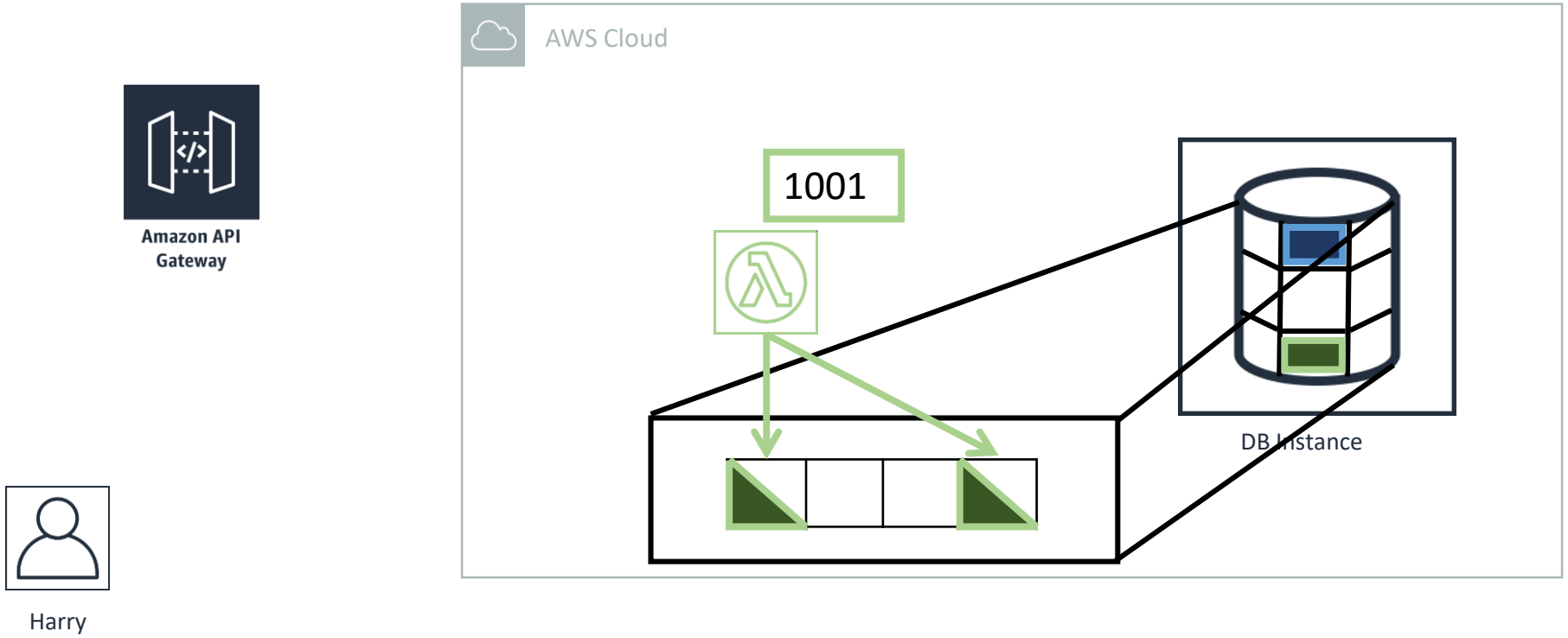
Closing the Termination Channel

Modified read and write semantics



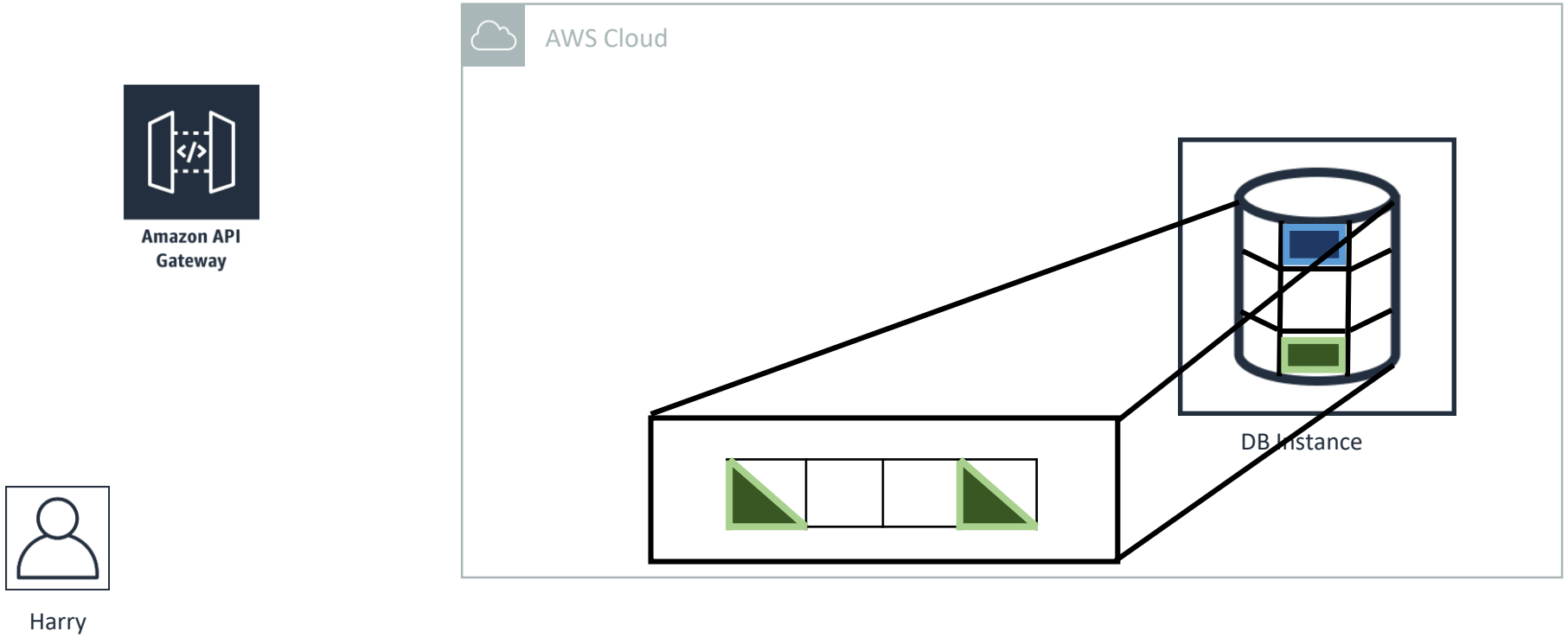
Closing the Termination Channel

Writes add a facet to the location, instead of overwriting



Closing the Termination Channel

An execution only sees the facets that is allowed to see



Closing the Termination Channel

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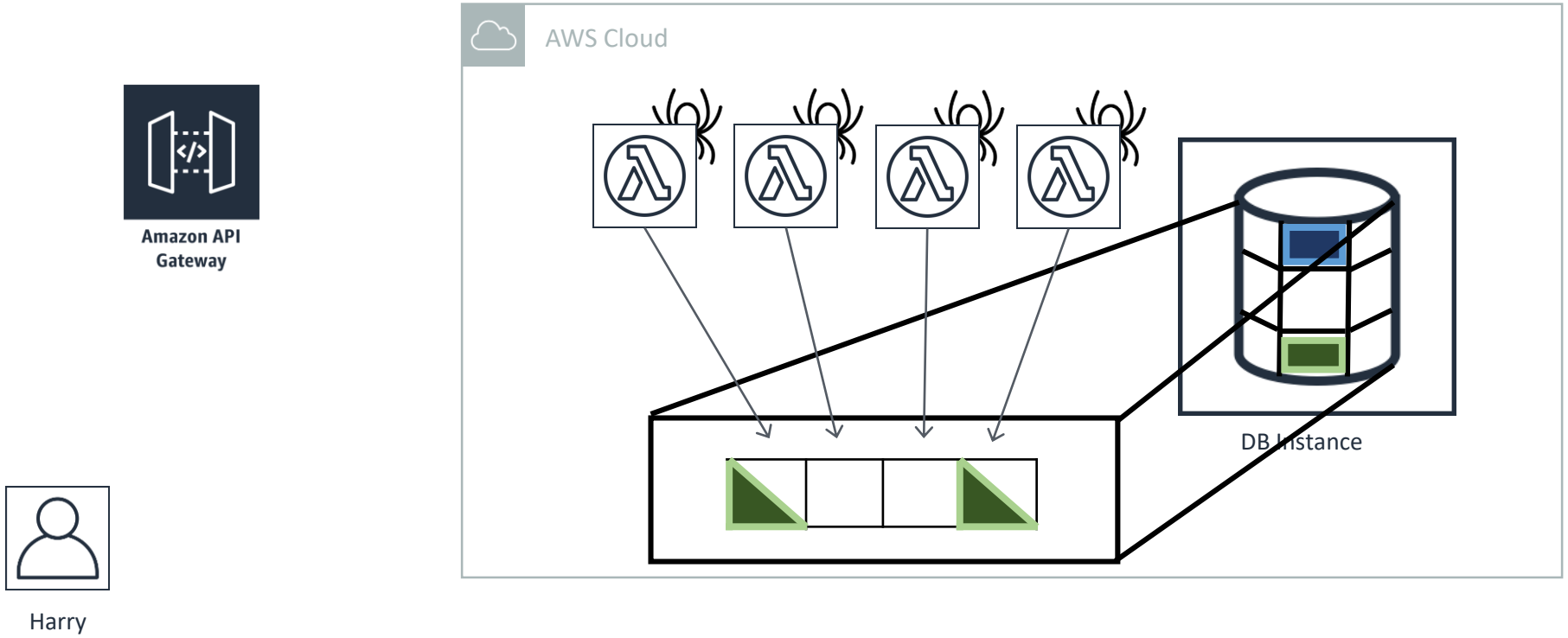
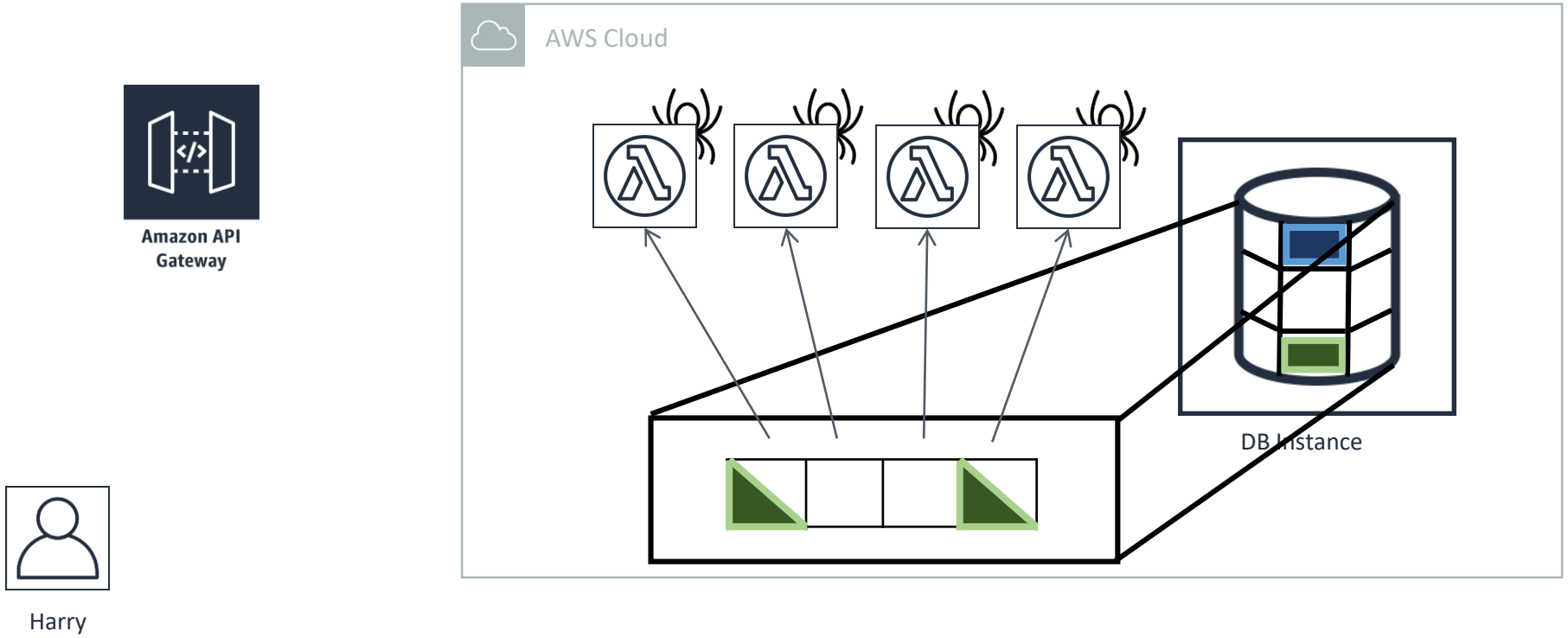


Closing the Termination Channel

An execution without the correct label can't distinguish between an empty cell, and a faceted cell



Trapeze

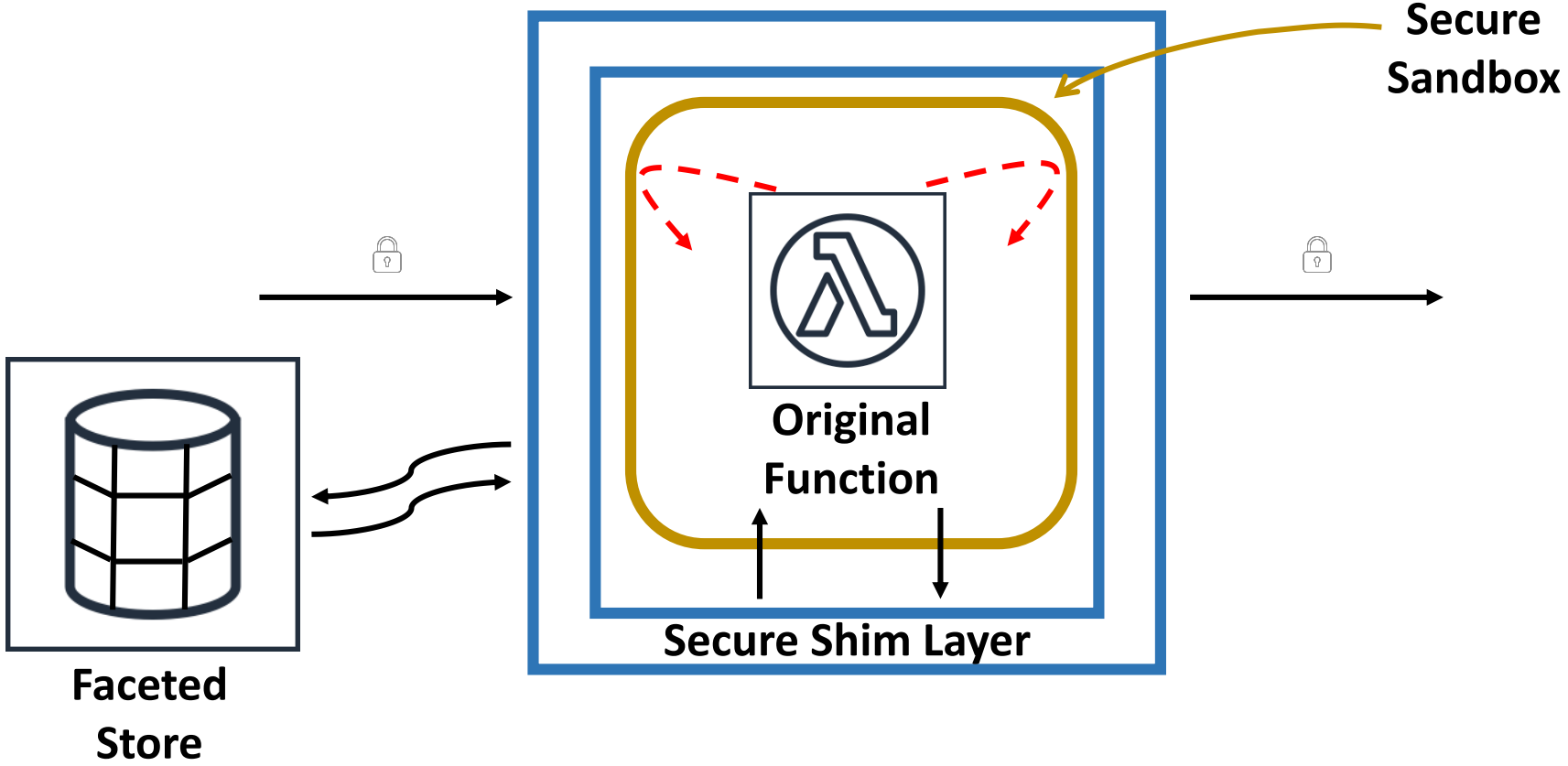
- Runtime enforcement of *Termination Sensitive Non-Interference*
  - Attacker cannot leak information by affecting execution termination
- Function executions get a security label when invoked
  - Label matches the security privilege of the invoker
- Faceted data store semantics
  - Items in the DB may have multiple values
  - Depending on the security label of the function that wrote the data

Trapeze – Goals

- Practical IFC system for serverless applications
- Low overhead in runtime
- Allow running existing application securely with minimal modification
- Transparency – secure applications have the same semantics as when running without Trapeze

Trapeze Architecture

Shim layer wraps functions, controlling communication and enforcing faceted store semantics



Evaluation

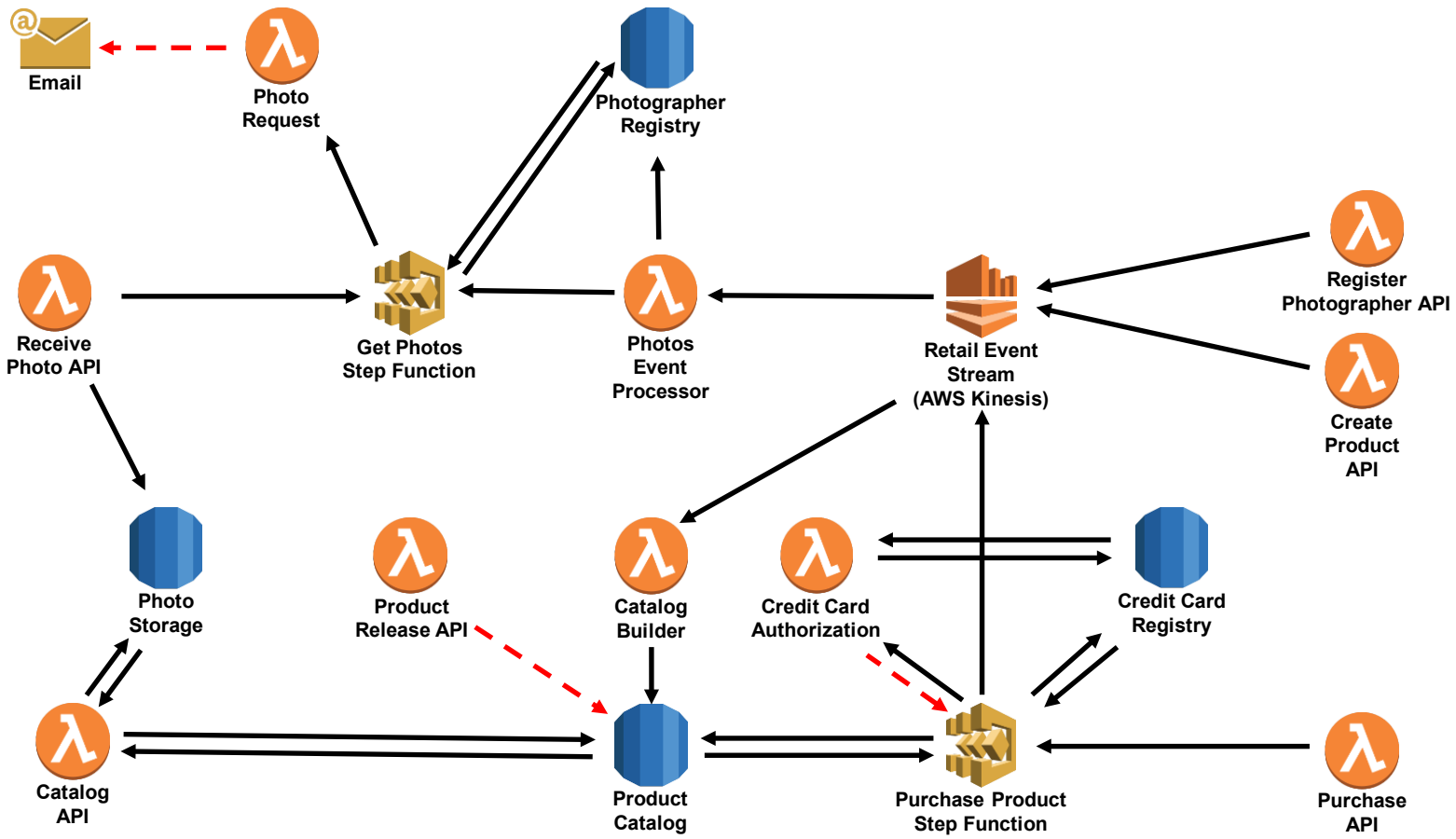
Test cases:

- Nordstrom Hello, Retail!
- gg
- Image feature extraction

Questions:

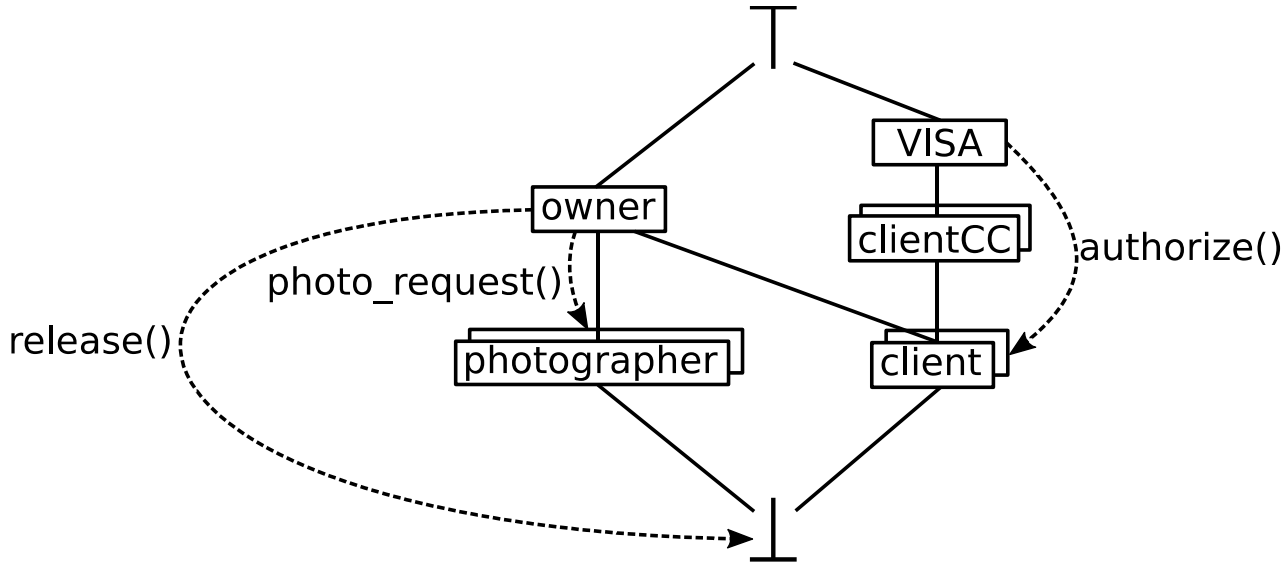
- Performance
- Ease of deployment
- Transparency

Evaluation – Hello, Retail!



Evaluation – Hello, Retail!

Security policy:



Evaluation Results

Scenario	#λ	λ runtime (ms)		Δ(%)	App. code	Modified
		baseline	Trapeze			
Hello, Retail!						
Update & Purchase	435	51,246	98,563	92.33	1300	3
Build & Browse	955	257,799	391,900	52.03		
gg						
mosh	111	681,173	654,448	-3.92	8800	2
git	917	2,602,500	2,660,721	2.24		
vim	234	1,242,873	1,338,128	7.66		
openssh	654	1,626,233	1,649,139	1.41		
Image Feature Extraction						
Upload	1	475	525	10.4	95	0
Extract	1	1,882	2,114	12.3		

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Summary

- Serverless computing
  - Security Risks
  - Security opportunities

- Trapeze
  - A practical IFC system for serverless applications
    - Guarantees TSNI
  - Low overhead (mostly) thanks to function granularity
  - High transparency

GitHub https://github.com/kalevalp/trapeze