AD Miner

(aka Bloodhound on steroids)

Offensive & defensive assessment of Active Directory infrastructures

Emilien Vannier
Jean-Michel Besnard
Tanguy Boisset

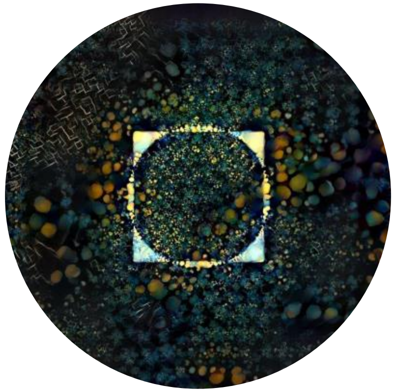
June 2024

Who we are

Jean-Michel Besnard
@jmbesnard_maz

Grant Thornton

#HIRING



Emilien Vannier
@dreamkinn

Tanguy Boisset
@Sopalinge

forvis mazars

… and a series of other contributors

Why securing Active Directory is key

- Active Directory (on-prem & Azure/Entra) is :
  - Central to most IT infrastructures
  - Obviously critical in terms of security

- For short, if you own the AD, you own almost the whole Information System

- Yet it often exposes a LOT of weaknesses (that, often, survived decades of bad practices)

- Therefore, is involved in an estimated 90% of ransomware attacks (*source: Mandiant*)

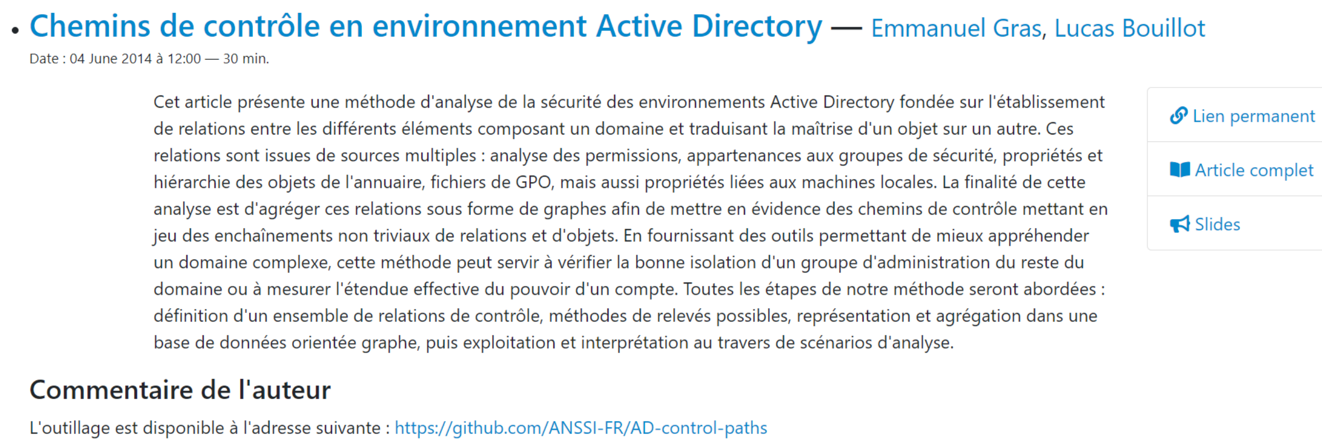
- Hence, requires :
  - Assessments to mitigate the risks
  - Regular monitoring to spot new issues

Existing tools to assess Active Directory

- Commercial tools : probably good but VERY **expensive**
- ANSSI ADS : closed source
- Free/opensource solutions (not a thorough list):
  - PingCastle : good but mostly for **defensive** side (and almost no graphs)
  - Purple Knight : same same
  - BTA : great but requires NTDS in the first place (and again, no graphs)
  - Bloodhound : excellent but mostly offensive + other **limitations** (listed after)

Graph representation

- 10 years ago (almost to the day), at SSTIC 2014 :
  - First academic paper leveraging the power of graph representation for AD auditing
  - Implementation in a tool name **AD Control Paths** (GH repo is now archived)



- Chemins de contrôle en environnement Active Directory — Emmanuel Gras, Lucas Bouillot

Date : 04 June 2014 à 12:00 — 30 min.

Cet article présente une méthode d'analyse de la sécurité des environnements Active Directory fondée sur l'établissement de relations entre les différents éléments composant un domaine et traduisant la maîtrise d'un objet sur un autre. Ces relations sont issues de sources multiples : analyse des permissions, appartenances aux groupes de sécurité, propriétés et hiérarchie des objets de l'annuaire, fichiers de GPO, mais aussi propriétés liées aux machines locales. La finalité de cette analyse est d'agréger ces relations sous forme de graphes afin de mettre en évidence des chemins de contrôle mettant en jeu des enchaînements non triviaux de relations et d'objets. En fournissant des outils permettant de mieux appréhender un domaine complexe, cette méthode peut servir à vérifier la bonne isolation d'un groupe d'administration du reste du domaine ou à mesurer l'étendue effective du pouvoir d'un compte. Toutes les étapes de notre méthode seront abordées : définition d'un ensemble de relations de contrôle, méthodes de relevés possibles, représentation et agrégation dans une base de données orientée graphe, puis exploitation et interprétation au travers de scénarios d'analyse.

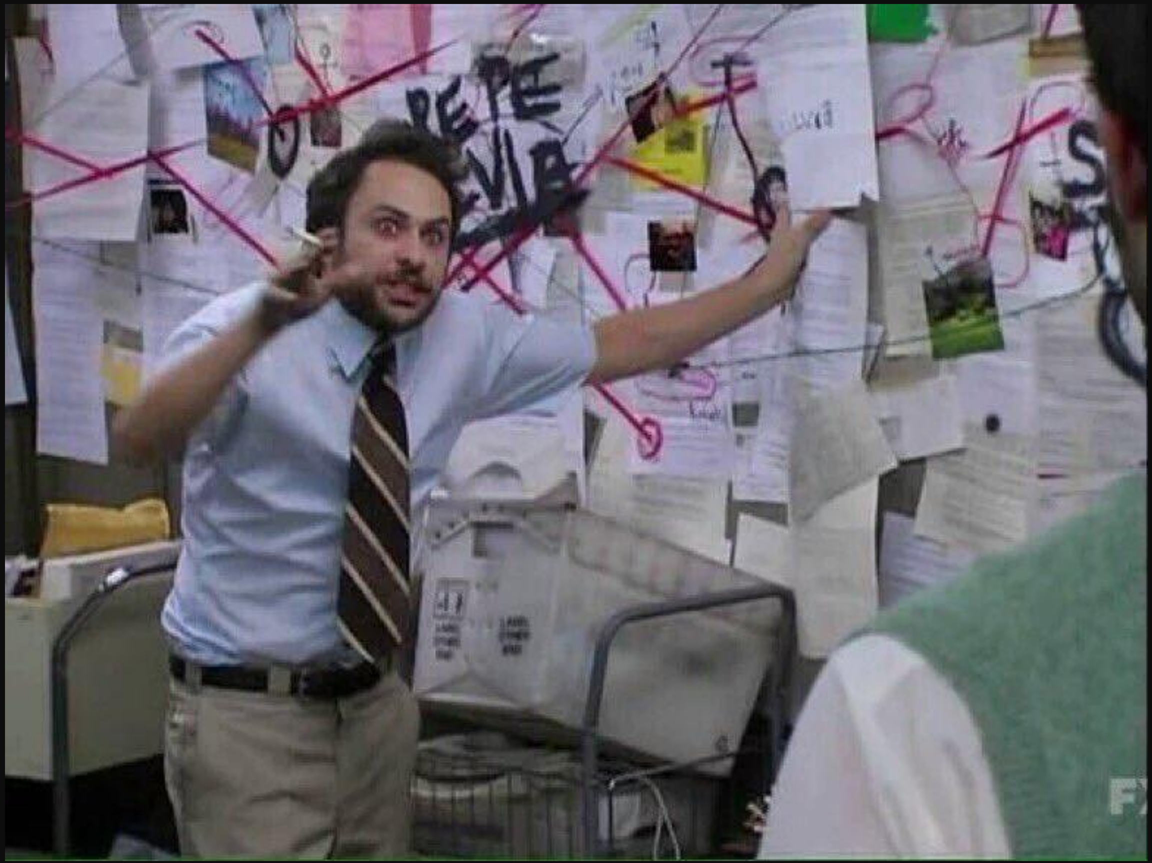
Commentaire de l'auteur

L'outillage est disponible à l'adresse suivante : https://github.com/ANSSI-FR/AD-control-paths

- 2 years later, in Nov. 2016, at BlackHat Arsenal Europe :
  - First release of **Bloodhound** by Andy Robins (@_wald0)
  - Also relies on graph representation
  - Receives a lot of attention and success

Graph representation

- What is graph representation and how can we use it in the context of AD ?

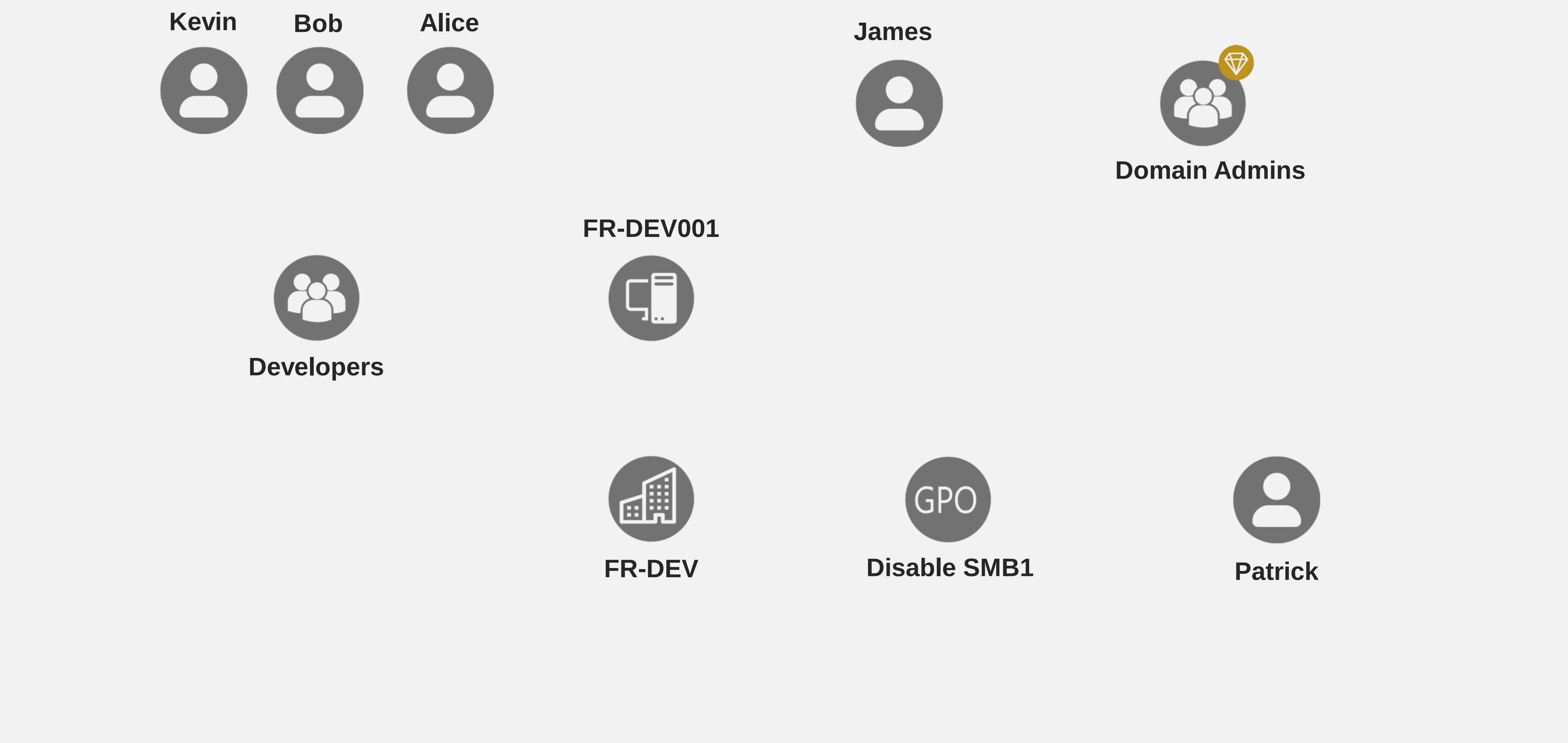


Graph representation

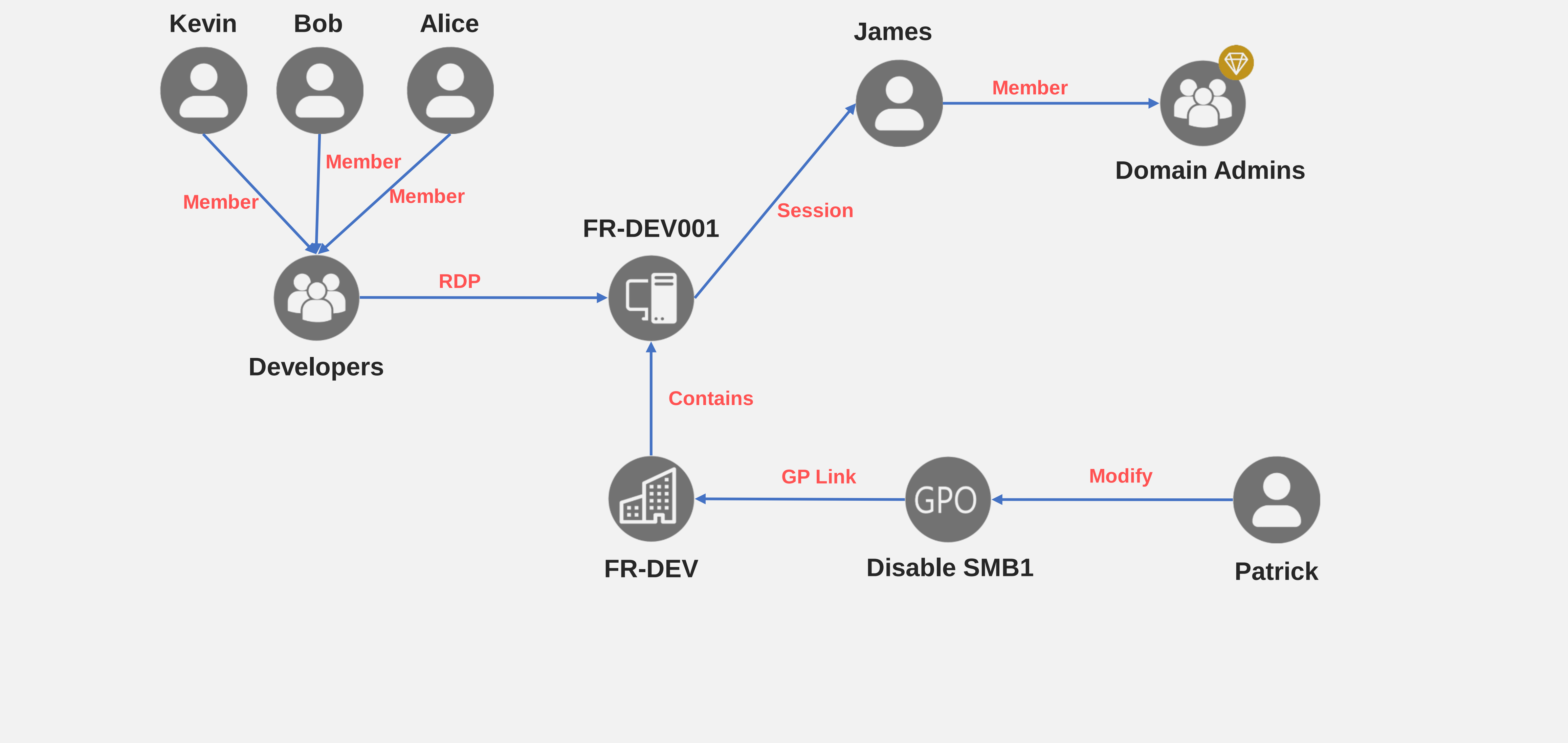
- What is graph representation and how can we use it in the context of AD ?

- Consider the following enumerated information :
  - **Kevin, Bob and Alice** are members of the **AD group "Developers"**
  - Members of that group can RDP to computer **FR-DEV001**
  - **James** has an active session on **computer FR-DEV001**
  - **James** is member of **Domain Admins**
  - **Patrick** can modify a **GPO named "Disable SMB1"**
  - That GPO is linked to **OU "FR-DEV"**
  - **OU "FR-DEV"** contains **computer FR-DEV001**

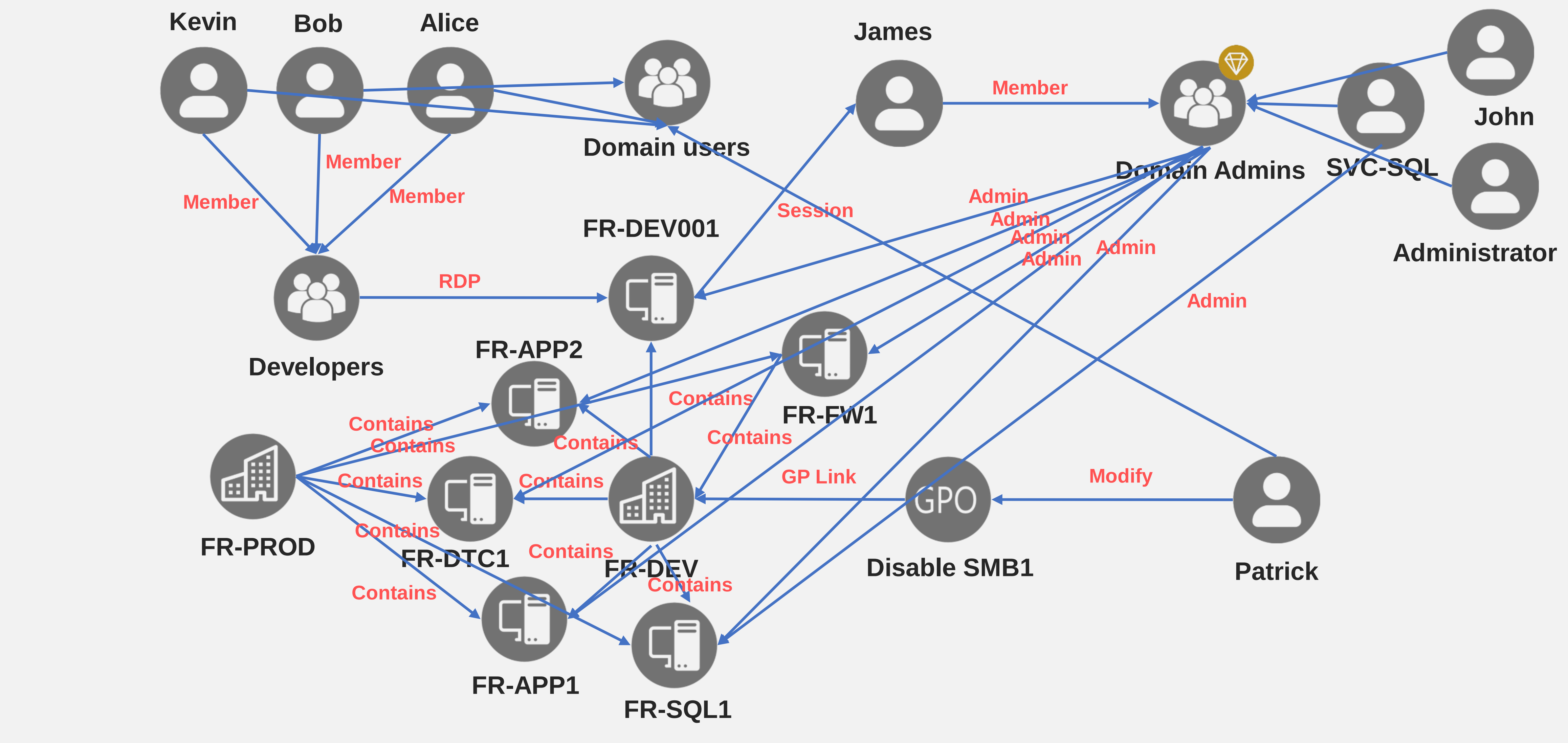
Graph representation



Graph representation



Graph representation



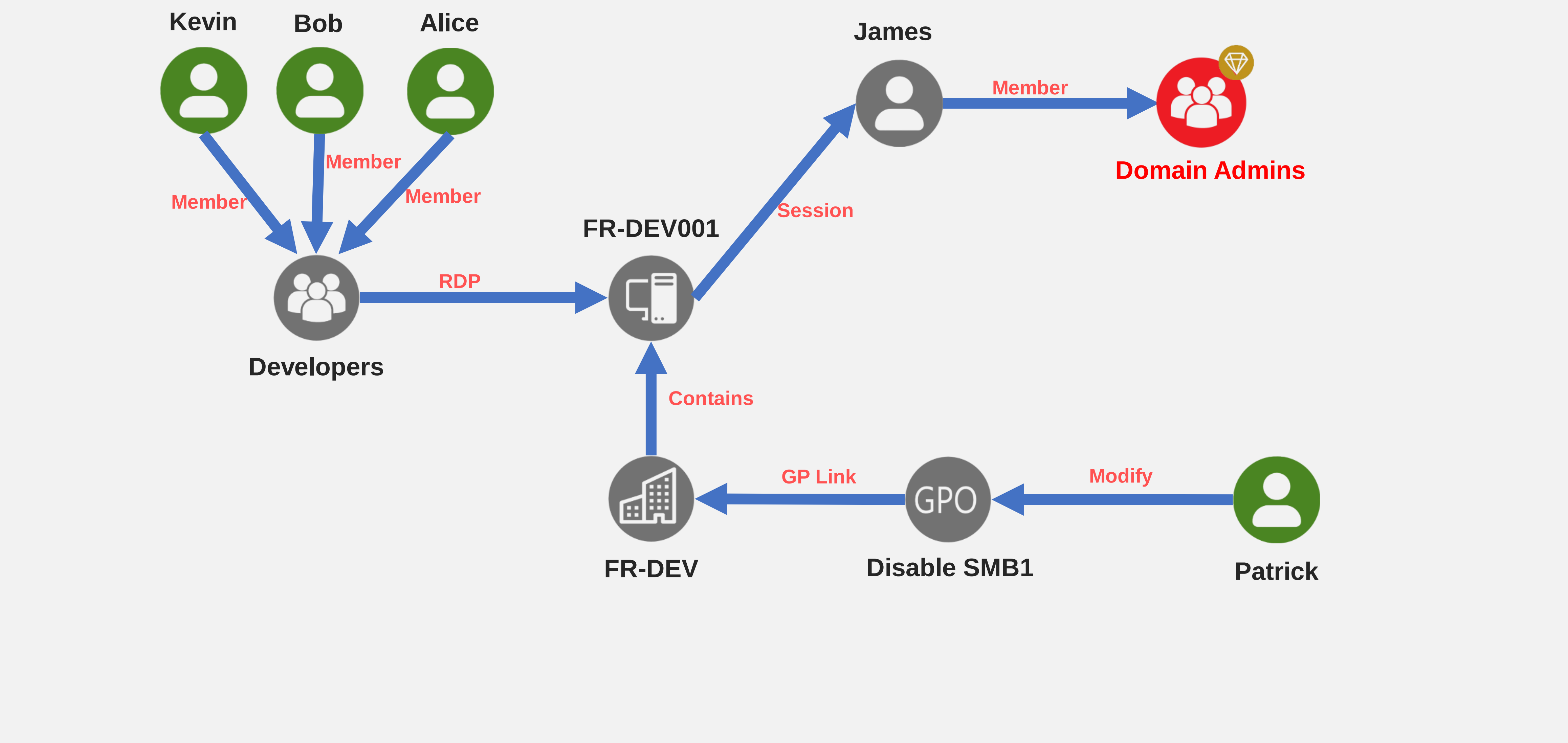
Graph representation

- These nodes and relations can be created in a graph database (ex: Neo4j)

- Then, a simple cypher query can reveal all control paths

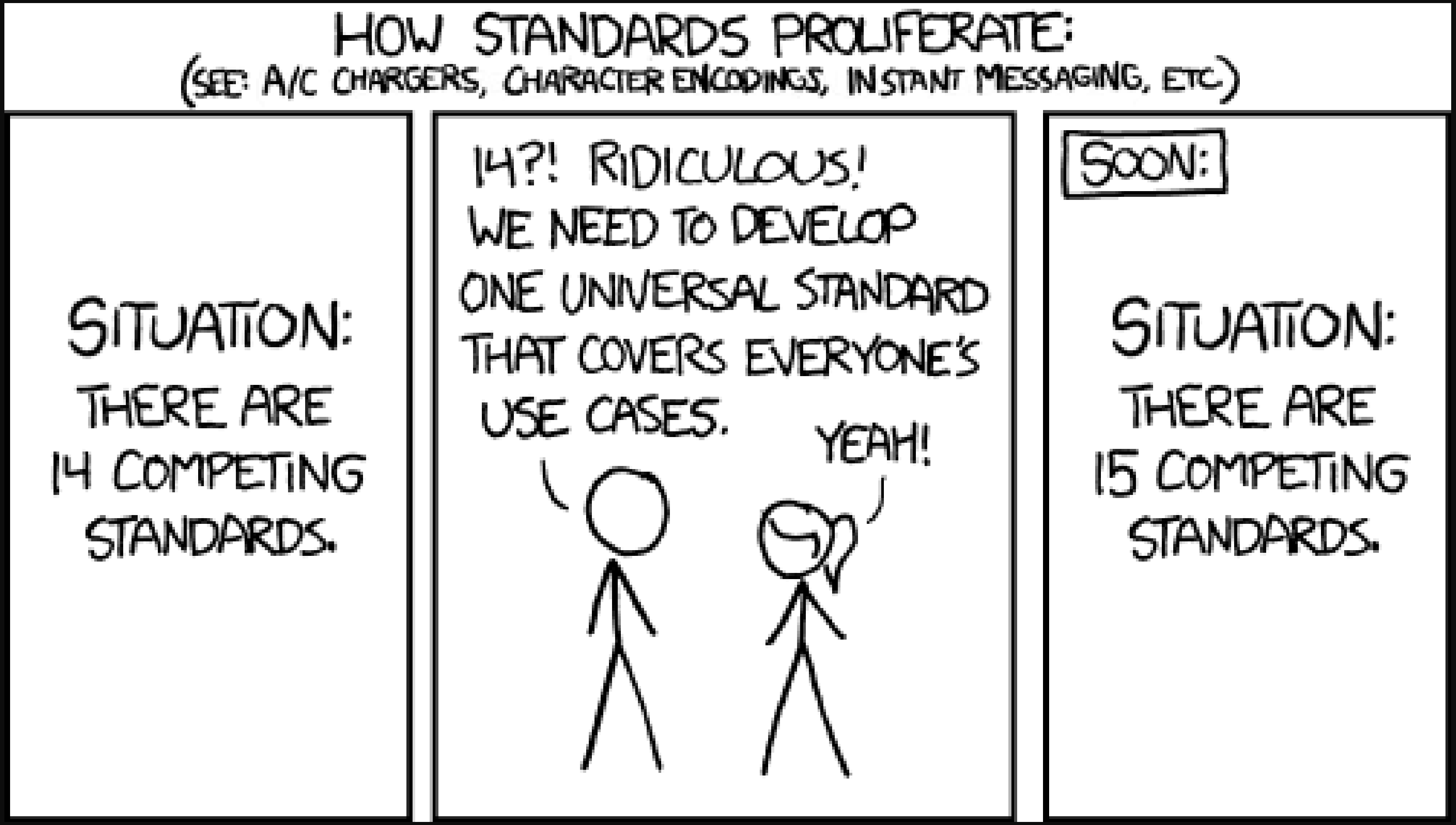
```
MATCH paths=(n)-[Member|Session|Admin|GP Link|Contains|Modify*1..]->(m{name:”Domain Admins”})
RETURN paths
```

Graph representation



A new tool to rule them all

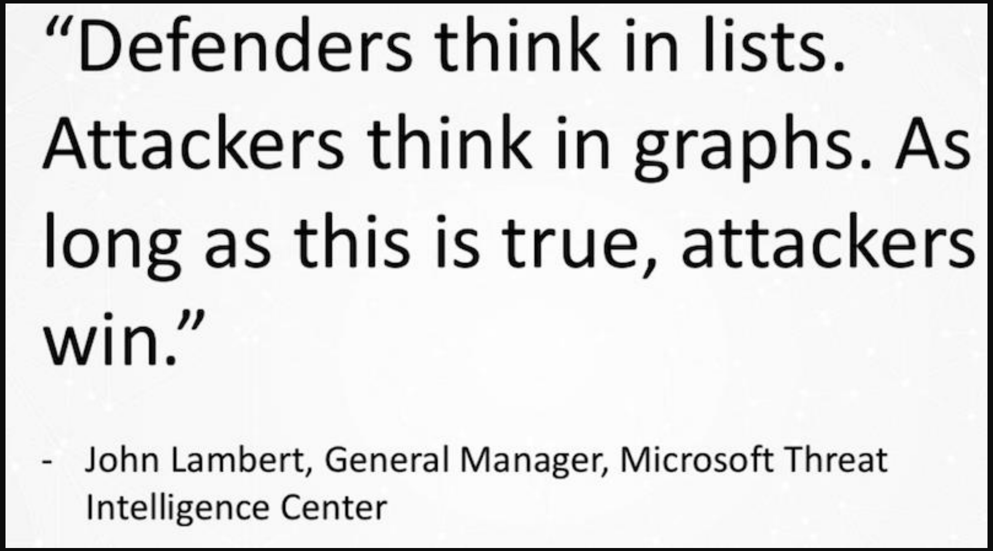
- Why developing yet another tool ?


HOW STANDARDS PROLIFERATE:
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC)
SITUATION: THERE ARE 14 COMPETING STANDARDS.
14?! RIDICULOUS! WE NEED TO DEVELOP ONE UNIVERSAL STANDARD THAT COVERS EVERYONE'S USE CASES.
YEAH!
SOON:
SITUATION: THERE ARE 15 COMPETING STANDARDS.

A new tool to rule them all

- Graph representation has a lot a potential

- As-is, Bloodhound is great but :
  - does not make the most out of its potential
  - can only plot **graphs**
  - is missing out on things where lists are better suited
  - can be difficult to use (unless you get your hands deep into cypher queries to fine-tune results)
  - Not really fit for defense/control activities

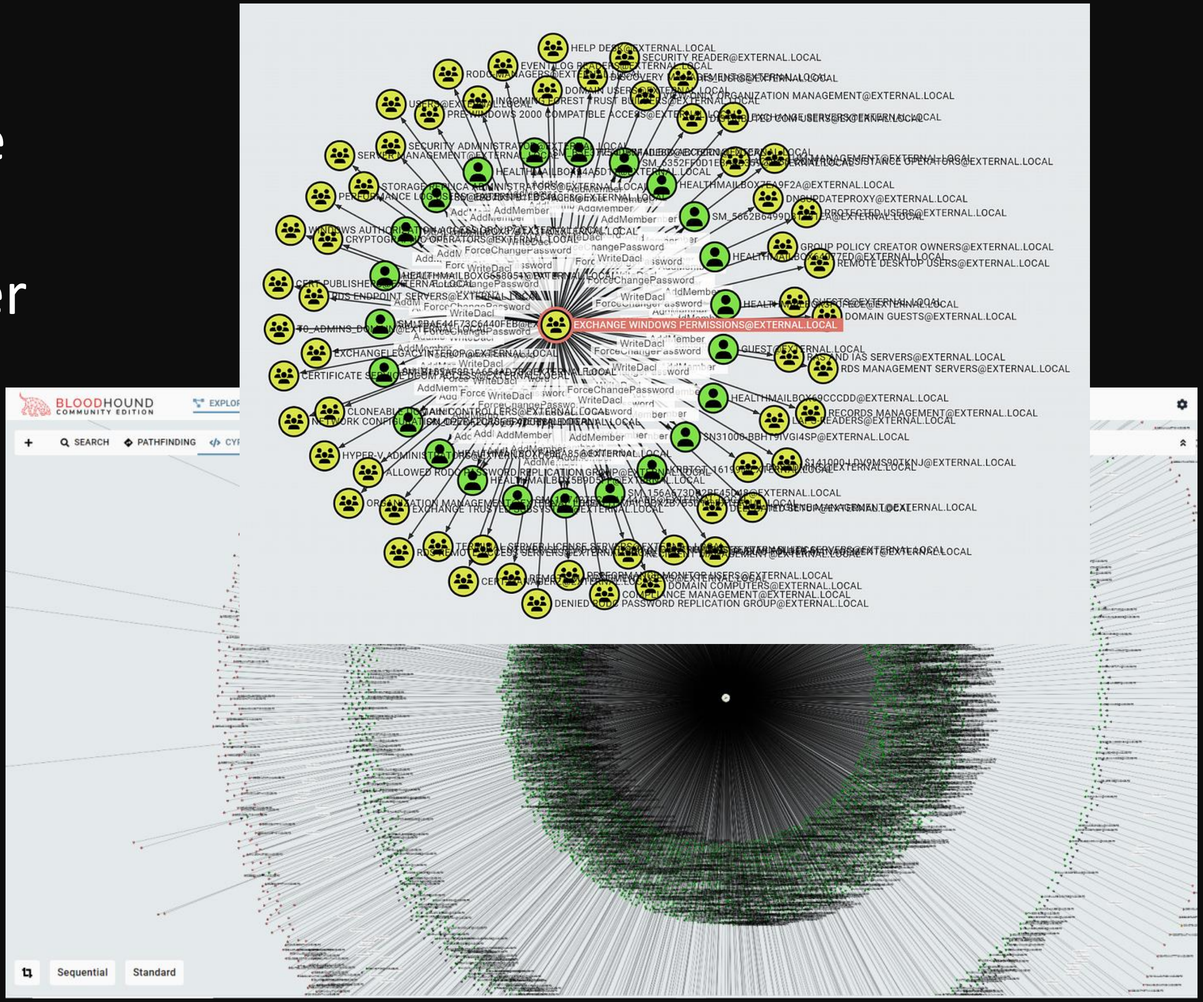


"Defenders think in lists. Attackers think in graphs. As long as this is true, attackers win."

- John Lambert, General Manager, Microsoft Threat Intelligence Center

A new tool to rule them all

- As-is, Bloodhound is great but (continued…):
  - is not ideal for non/less-tech savvy people
  - includes some controls (i.e., default cypher queries) but those are
    - rather limited
    - very generic
    - may show all problems at once
      - **very heavy graphs** that may be difficult to navigate
  - requires to run queries for each control
    - Can take a **very long time**


BLOODHOUND
COMMUNITY EDITION
EXPLORE
SEARCH
PATHFINDING
CYPHER
Sequential
Standard
EXCHANGE WINDOWS PERMISSIONS@EXTERNAL.LOCAL
HELP DESK@EXTERNAL.LOCAL
SECURITY READER@EXTERNAL.LOCAL
ORGANIZATION MANAGEMENT@EXTERNAL.LOCAL
PRE-WINDOWS 2000 COMPATIBLE ACCESS@EXTERNAL.LOCAL
DNSUPDATEPROXY@EXTERNAL.LOCAL
PROTECTED USERS@EXTERNAL.LOCAL
GROUP POLICY CREATOR OWNERS@EXTERNAL.LOCAL
REMOTE DESKTOP USERS@EXTERNAL.LOCAL
DOMAIN GUESTS@EXTERNAL.LOCAL
RAS AND IAS SERVERS@EXTERNAL.LOCAL
RDS MANAGEMENT SERVERS@EXTERNAL.LOCAL
RECORDS MANAGEMENT@EXTERNAL.LOCAL
DOMAIN COMPUTERS@EXTERNAL.LOCAL
COMPLIANCE MANAGEMENT@EXTERNAL.LOCAL
DENIED RODC PASSWORD REPLICATION GROUP@EXTERNAL.LOCAL
CERTIFICATE SERVICE DCOM ACCESS@EXTERNAL.LOCAL
CERT PUBLISHERS@EXTERNAL.LOCAL
RDS ENDPOINT SERVERS@EXTERNAL.LOCAL
HYPER-V ADMINISTRATORS@EXTERNAL.LOCAL
ALLOWED RODC PASSWORD REPLICATION GROUP@EXTERNAL.LOCAL
AddMember
ForceChangePassword
WriteDacl

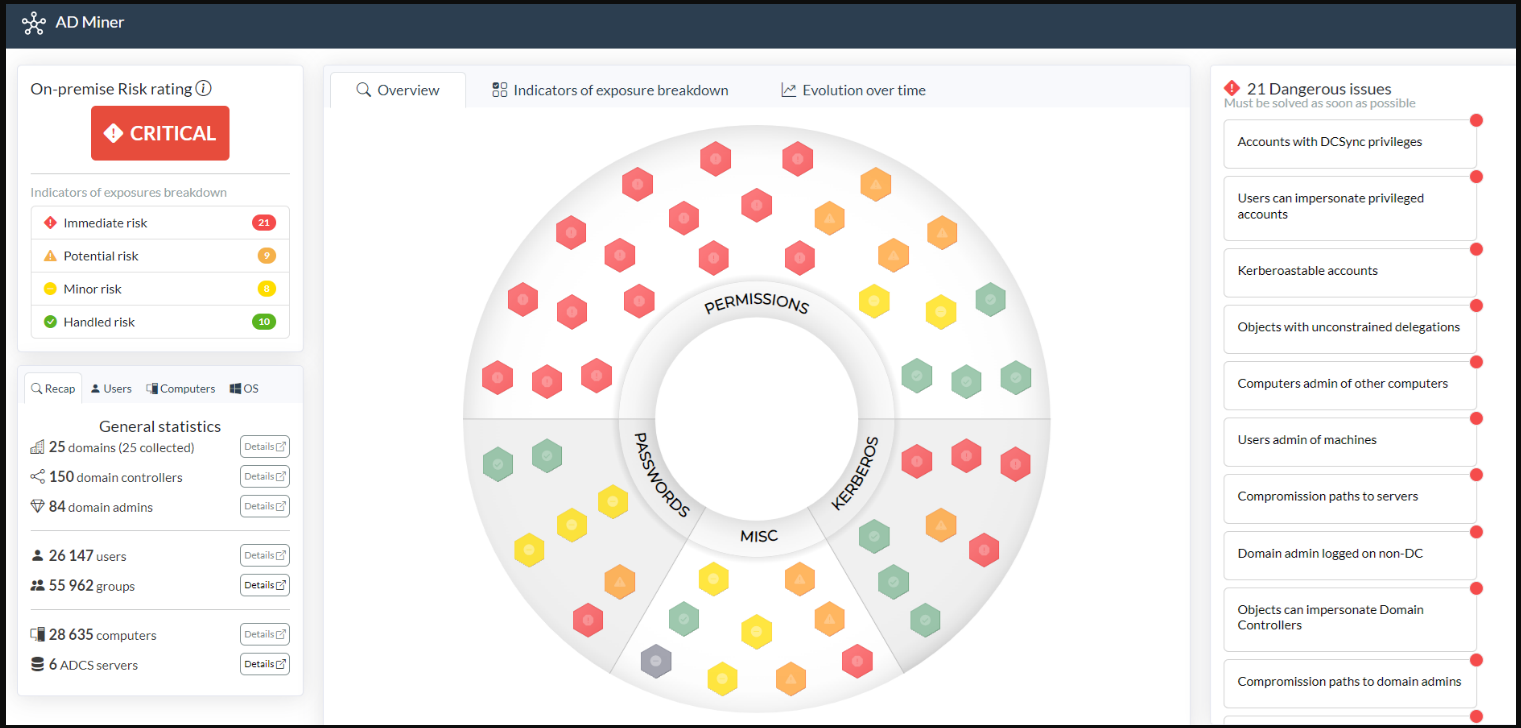
A new tool to rule them all

- What we wanted
  - Leverage the great aspects of Bloodhound (and Sharphound for data collection)
  - Run a constant series of fine-tuned controls **once and for all** (as of now 60+ controls)
  - Cover all controls already available in other tools (PingCastle, ADS, etc.)
  - Make something useful for:
    - **pentesters** who audit ADs and need to document/demo weaknesses
    - **defenders** who mitigate risks (KPI, ratings, evolution over time)
  - A good-looking, dynamic, web-based report that can be accessed offline and without a web server/database (aka static HTML)

A new tool to rule them all

AD Miner

- aka Bloodhound on steroids



AD Miner

On-premise Risk rating ⓘ

CRITICAL

Indicators of exposures breakdown

Immediate risk	21
Potential risk	9
Minor risk	8
Handled risk	10

Recap · Users · Computers · OS

General statistics

- 25 domains (25 collected) Details
- 150 domain controllers Details
- 84 domain admins Details
- 26 147 users Details
- 55 962 groups Details
- 28 635 computers Details
- 6 ADCS servers Details

Overview · Indicators of exposure breakdown · Evolution over time

21 Dangerous issues
Must be solved as soon as possible

- Accounts with DCSync privileges
- Users can impersonate privileged accounts
- Kerberoastable accounts
- Objects with unconstrained delegations
- Computers admin of other computers
- Users admin of machines
- Compromission paths to servers
- Domain admin logged on non-DC
- Objects can impersonate Domain Controllers
- Compromission paths to domain admins

- Yes, we did not make the smartest choice when naming the tool
  - And have learned it the hard way

Adminer
Database management in a PHP file

English · Slovenčina · Deutsch · Polski

Adminer · Adminer Editor · News · F · Bugs · Code

y phpMinAdmin) is a full-featured database ma ool written in PHP. Conversely to phpMyAdmin, it ingle file ready to deploy to the target server. e for MySQL, MariaDB, PostgreSQL, SQLite, , Orac search, MongoDB and others via plugin.

Se es, Requirements, Skins, References

Online de

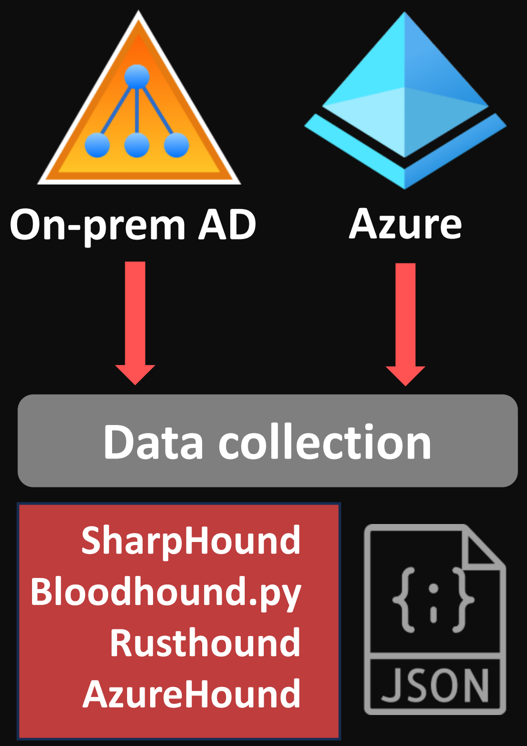
Download
v 4.8.1, 2021-05-14

Architecture

On-prem AD

Azure

Architecture



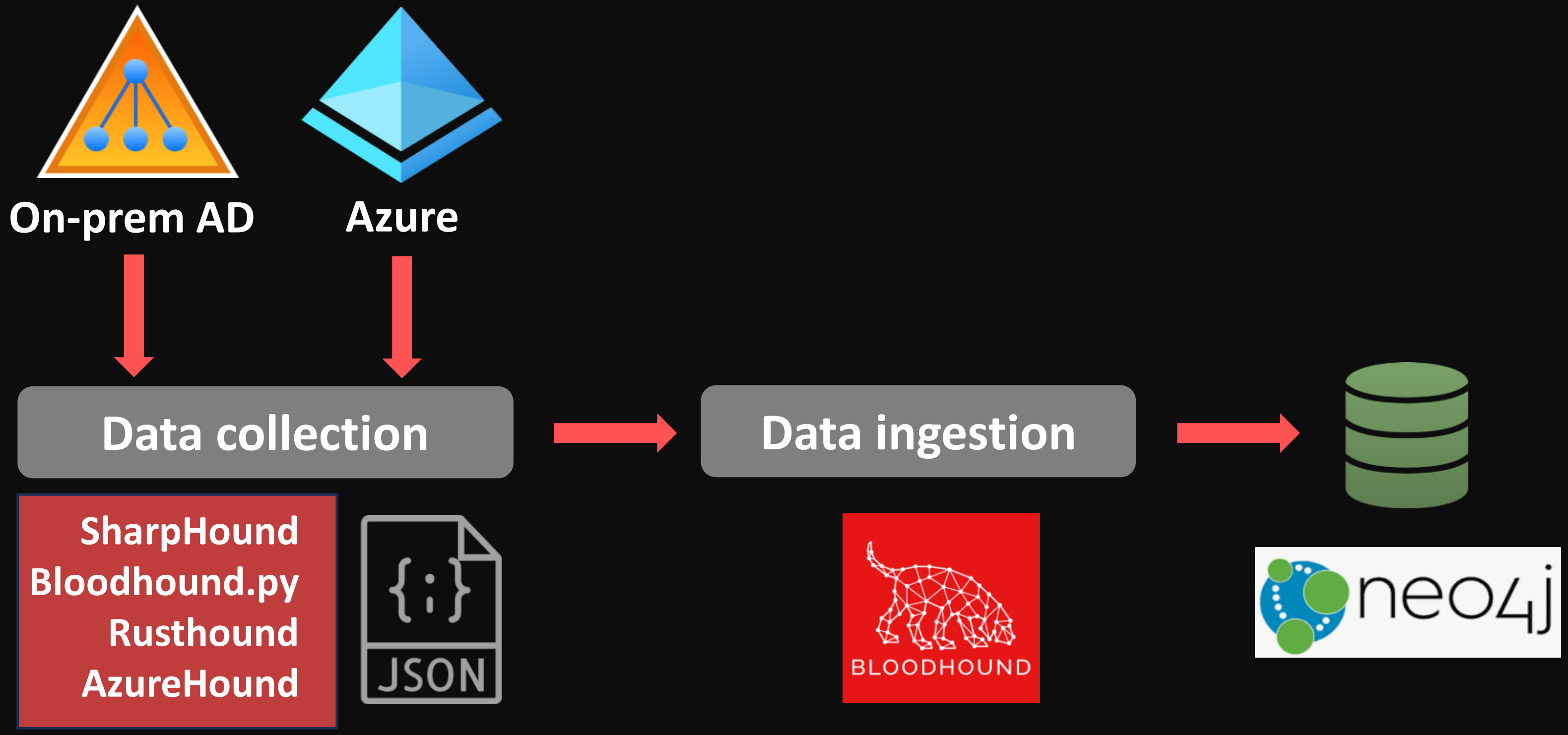
On-prem AD

Azure

Data collection

SharpHound
Bloodhound.py
Rusthound
AzureHound

Architecture



On-prem AD

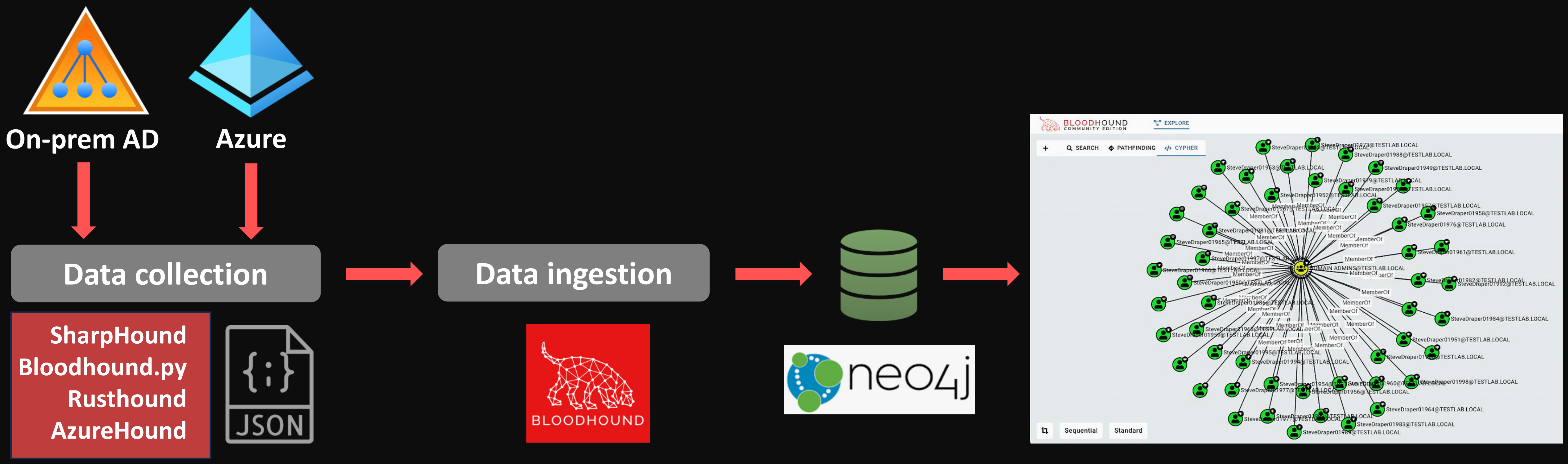
Azure

Data collection

SharpHound
Bloodhound.py
Rusthound
AzureHound

Data ingestion

Architecture



On-prem AD

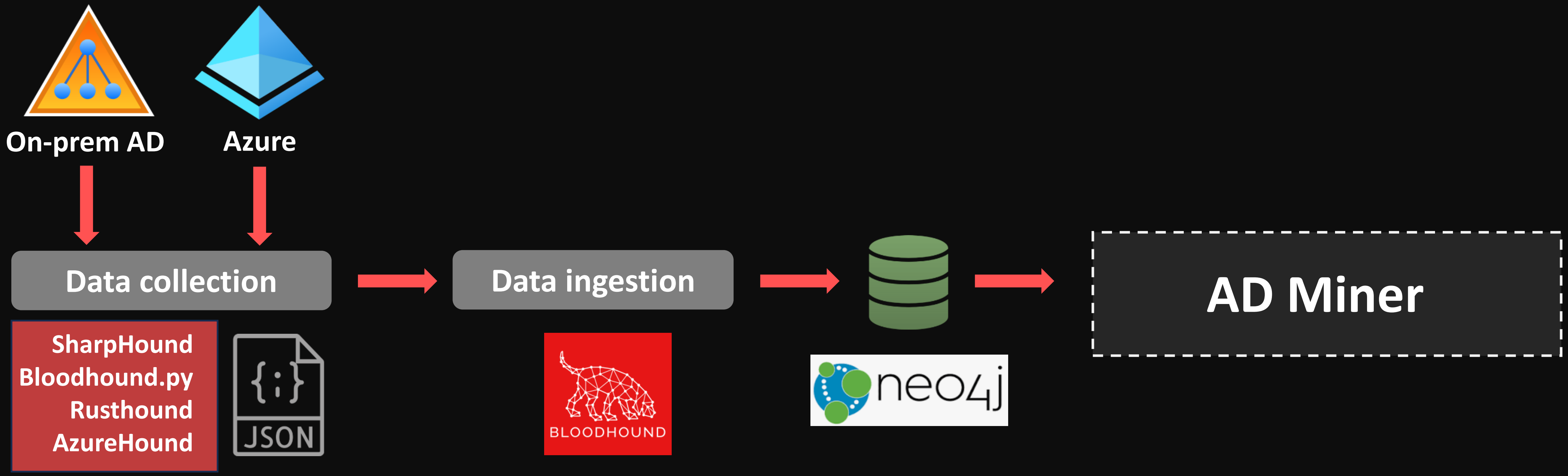
Azure

Data collection

SharpHound
Bloodhound.py
Rusthound
AzureHound

Data ingestion

Architecture



On-prem AD

Azure

Data collection

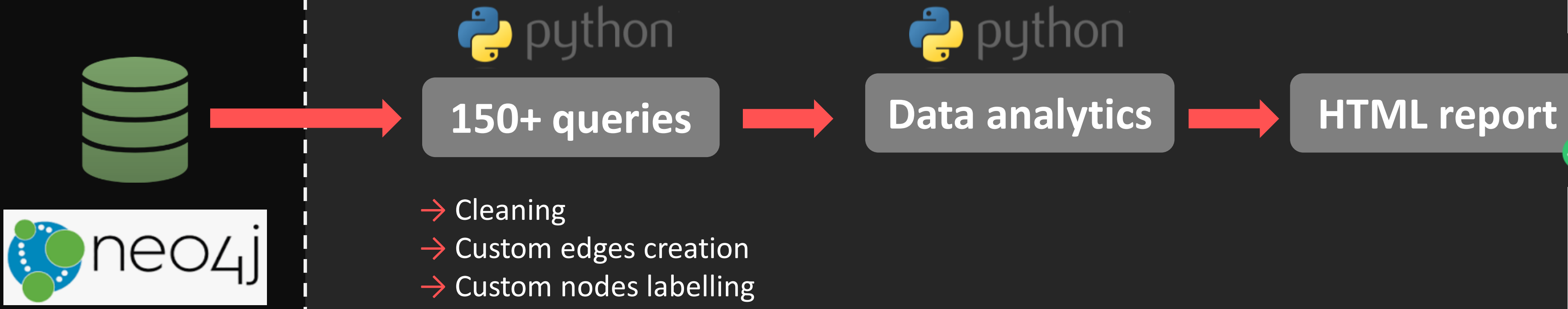
SharpHound
Bloodhound.py
Rusthound
AzureHound

Data ingestion

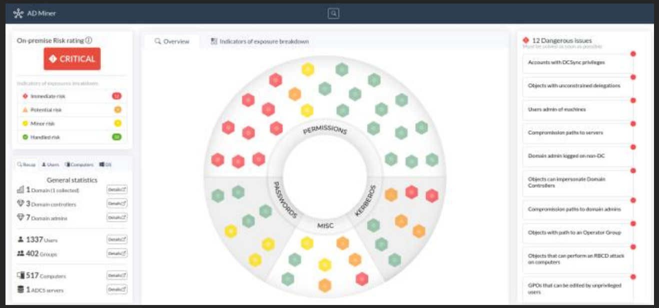
AD Miner

Architecture

AD Miner



→ Cleaning
→ Custom edges creation
→ Custom nodes labelling
→ Compromission paths
→ Dangerous configuration



On-premise Risk rating

CRITICAL

Indicators of exposure breakdown

- Immediate risk
- Potential risk
- Minor risk
- Handled risk

Recap | Users | Computers | OS

General statistics

1 Domain (1 collected)	Details
3 Domain controllers	Details
7 Domain admins	Details
1337 Users	Details
402 Groups	Details
517 Computers	Details
1 ADCS servers	Details

Overview | Indicators of exposure breakdown

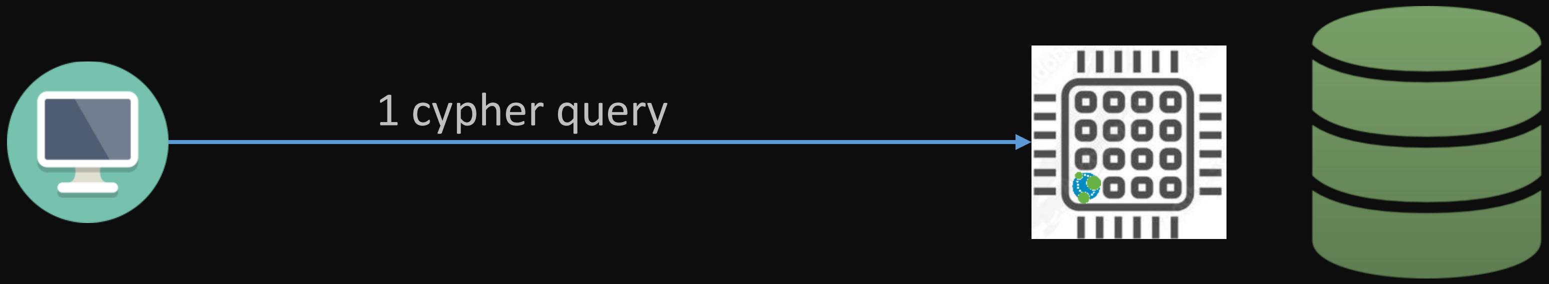
12 Dangerous Issues

Must be solved as soon as possible

- Accounts with DCSync privileges
- Objects with unconstrained delegations
- Users admin of machines
- Compromission paths to servers
- Domain admin logged on non-DC
- Objects can impersonate Domain Controllers
- Compromission paths to domain admins
- Objects with path to an Operator Group
- Objects that can perform an RBCD attack on computers
- GPOs that can be edited by unprivileged users

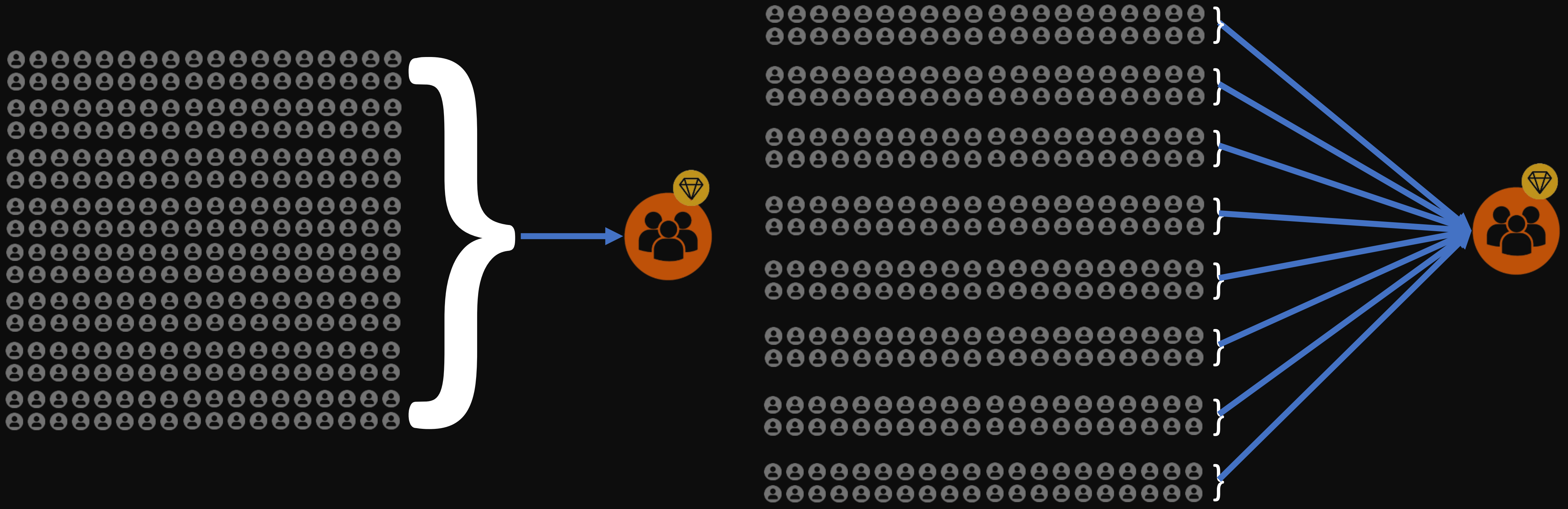
Innovations

- Graph database multi-threading
  - Cypher queries can be very CPU-intensive and take a long time to execute
  - Neo4j Community Edition uses only 1 CPU core per client request



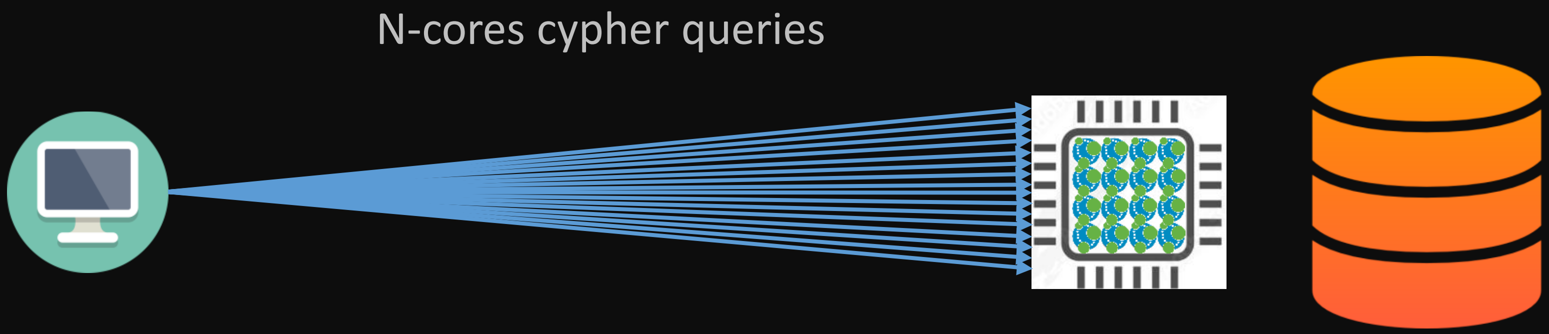
Innovations

- Graph database multi-threading
  - To get around this limitation, we have developed an easy solution:
    - Split cypher into smaller chunks (e.g., split source nodes space into 1000 chunks)



Innovations

- Graph database multi-threading
  - To get around this limitation, we have developed an easy solution:
    - Split cypher into smaller chunks (e.g., split source nodes space into 1000 chunks)
    - Run each chunk in N concurrents client queries

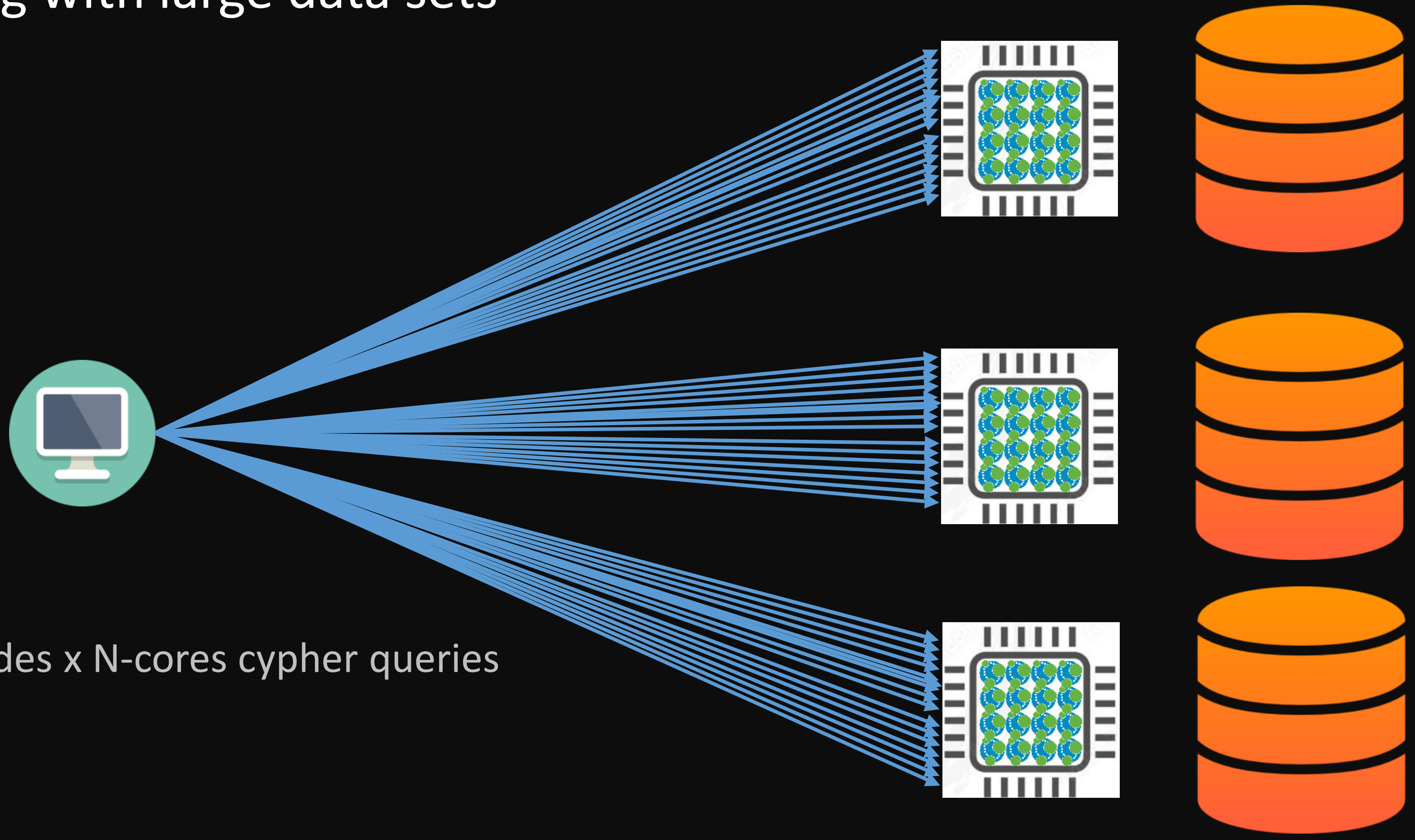


AD forest with 25K users on a 32-core CPU (e.g., Intel Core i9 13900)

- ~ 45 hours without multi-threading
- ~ 2 hours with multi-threading

Innovations

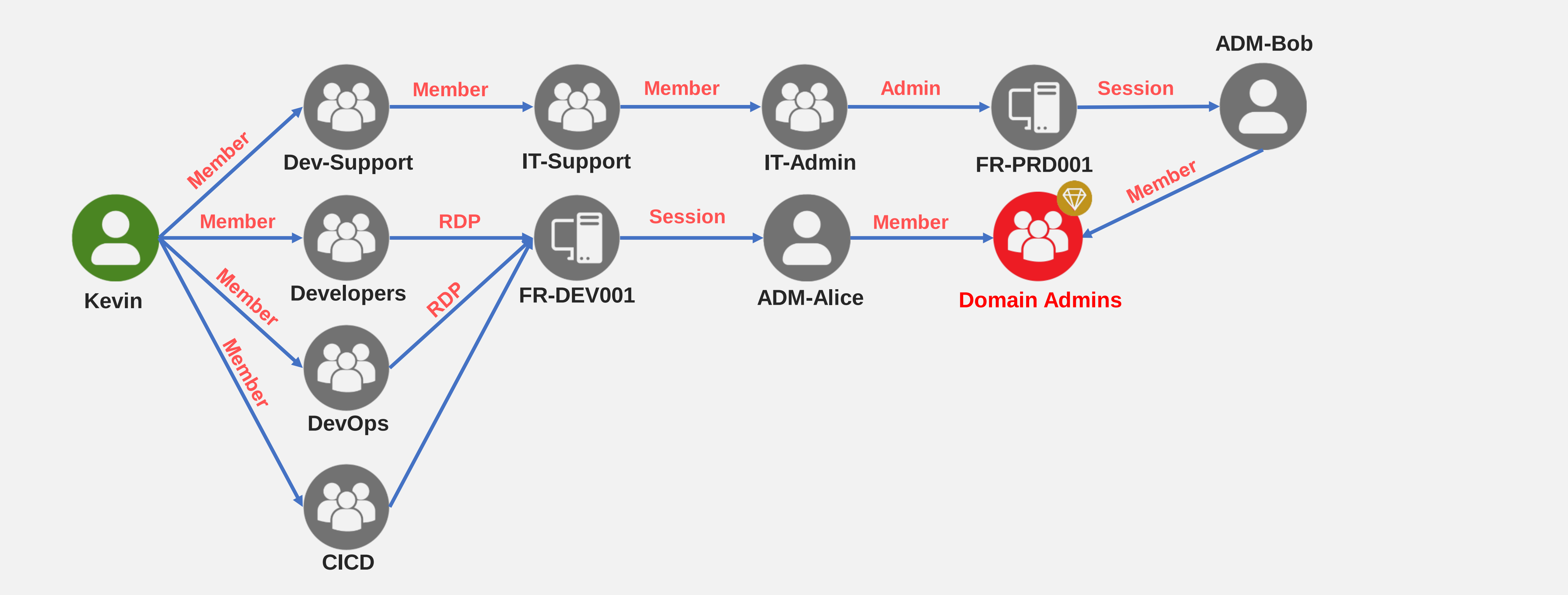
- Graph database multi-threading
  - And while we are at it, implement clustering to further maximize throughput when dealing with large data sets



N-cluster nodes x N-cores cypher queries

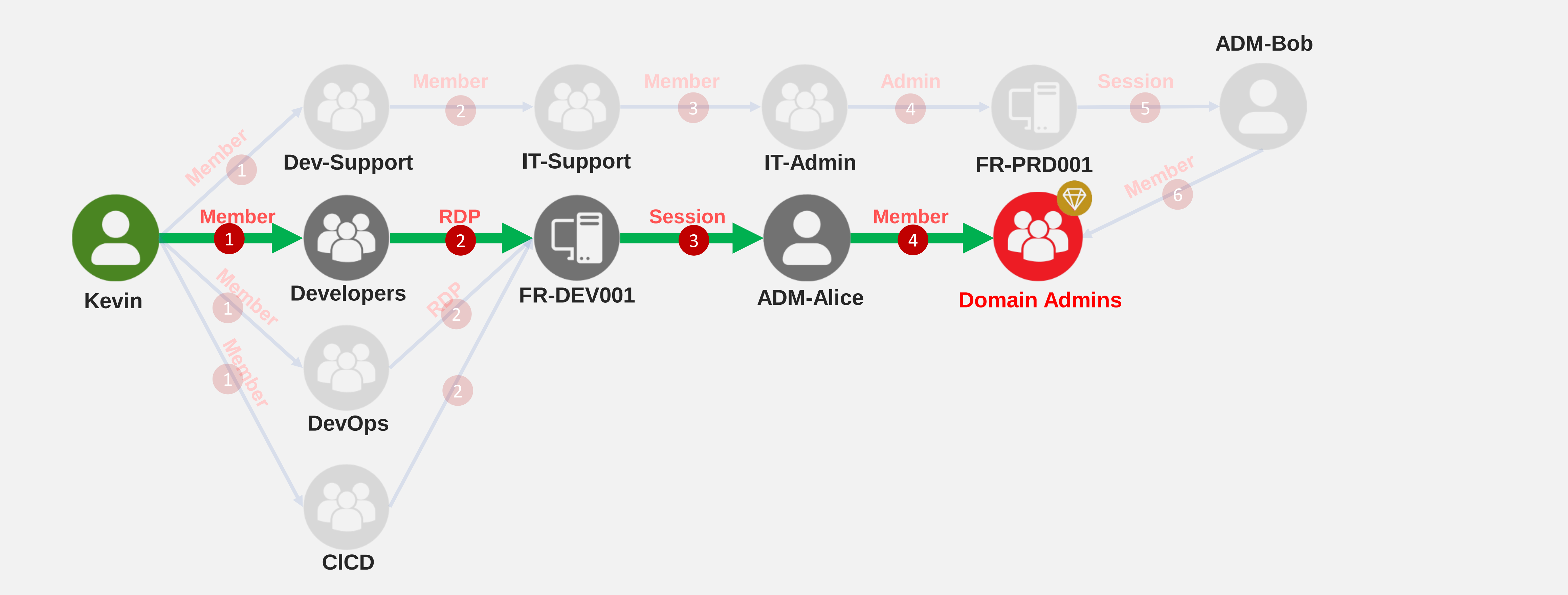
Innovations

- Path computation functions



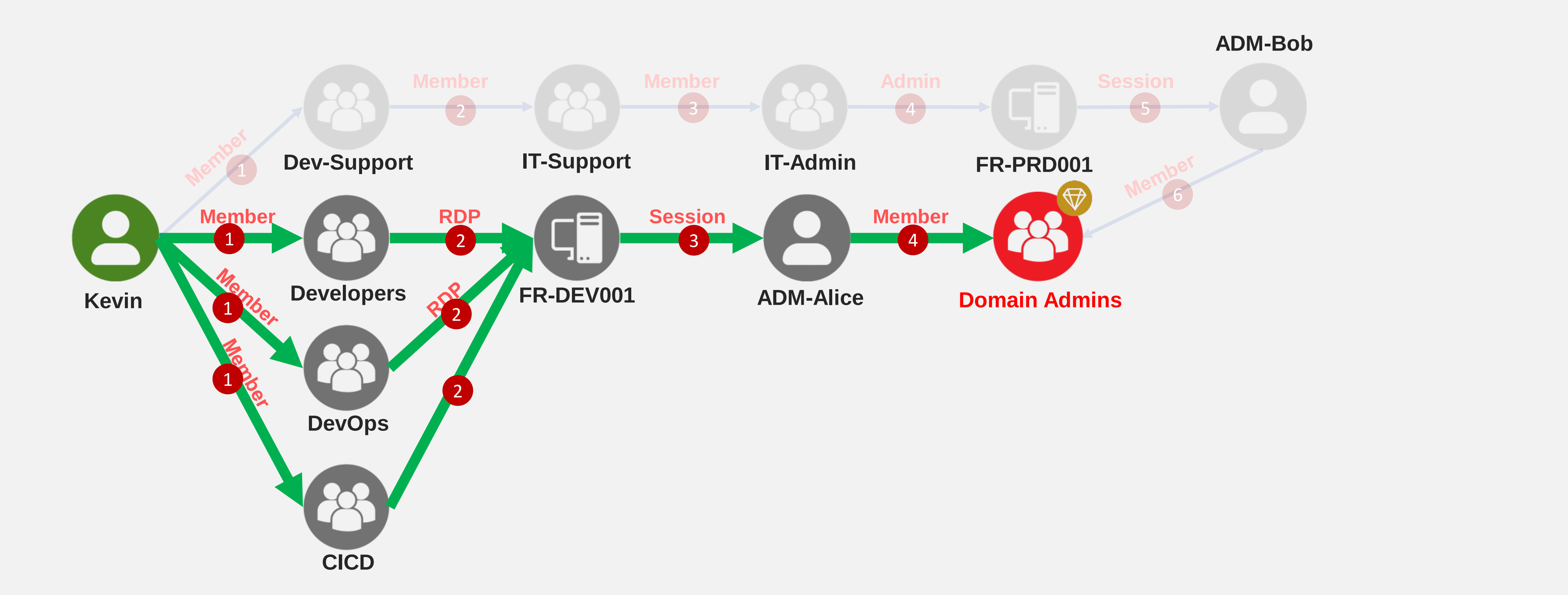
Innovations

- Path computation functions: **shortestPath()**
  - Return one of the paths with least hops



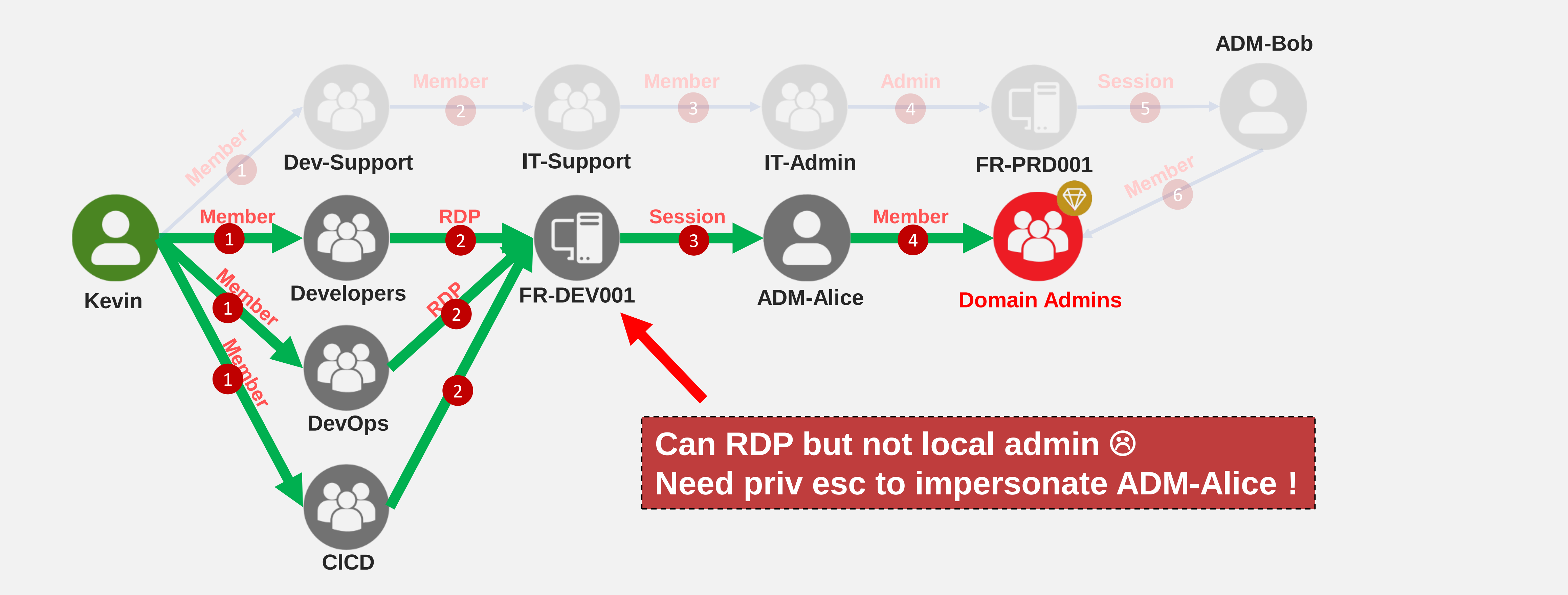
Innovations

- Path computation functions: **allShortestPaths()**
  - Returns all paths of length equal to shortest path



Innovations

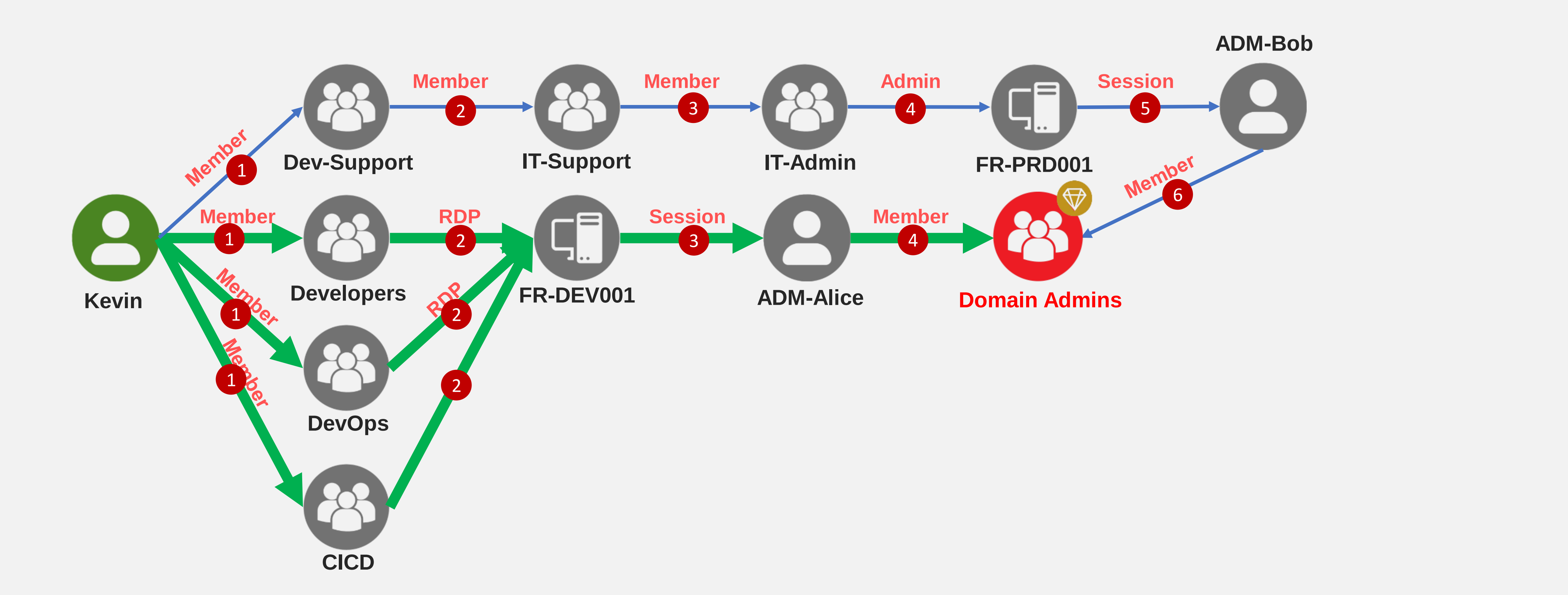
- Path computation functions: **allShortestPaths()**
    - Returns all paths of length equal to shortest path



Can RDP but not local admin ☹
Need priv esc to impersonate ADM-Alice !

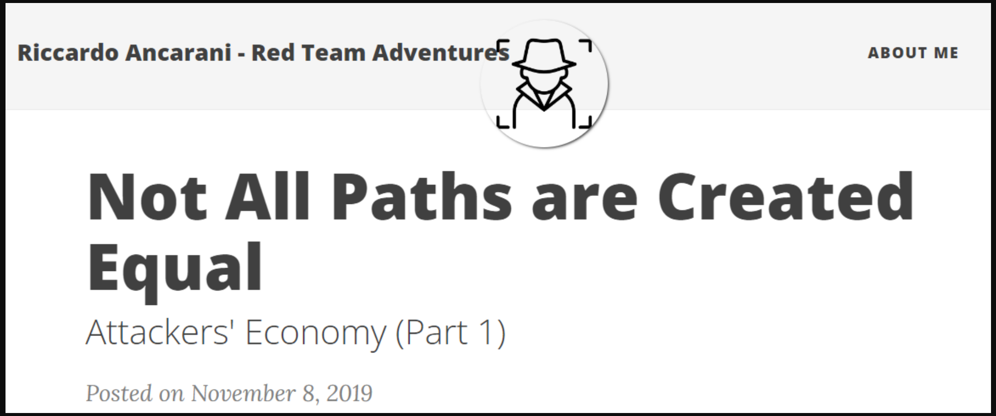
Innovations

- Path computation functions: allShortestPaths()
  - Returns all paths of length equal to shortest path



Innovations

- How to spot paths that are **easier to exploit** (even though these may cross more hops) ?

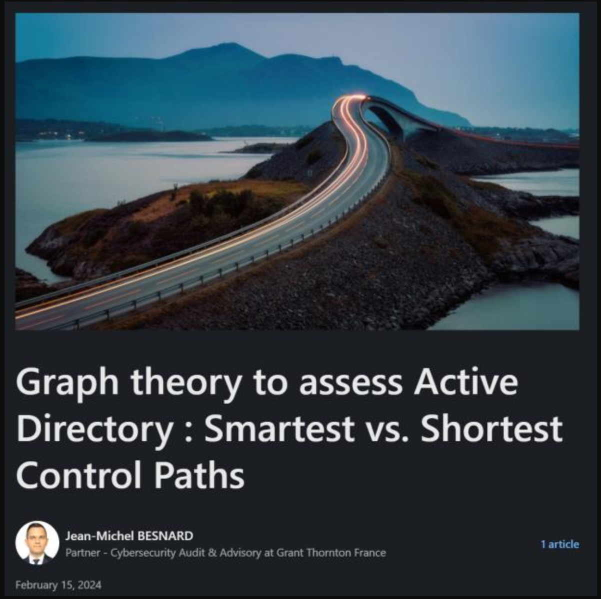


Riccardo Ancarani - Red Team Adventures

Not All Paths are Created Equal

Attackers' Economy (Part 1)

Posted on November 8, 2019



Graph theory to assess Active Directory : Smartest vs. Shortest Control Paths

Jean-Michel BESNARD

Partner - Cybersecurity Audit & Advisory at Grant Thornton France

February 15, 2024

- November 8th, 2019 blog post by Riccardo Ancarani on using weighted relations:
  - https://riccardoancarani.github.io/2019-11-08-not-all-paths-are-equal/

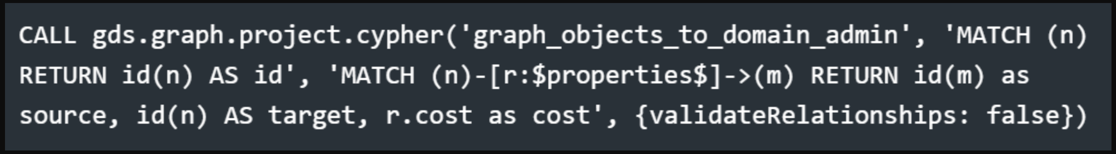
- Also illustrated here :
  - https://www.linkedin.com/pulse/graph-theory-assess-active-directory-smartest-vs-shortest-besnard-0qgle/

A new tool to rule them all

- Apply weights to relations (values can be modified in AD Miner config file). For example,
  - **MemberOf = 0 | CanRDP = 40 | AdminTo = 10 | etc…**

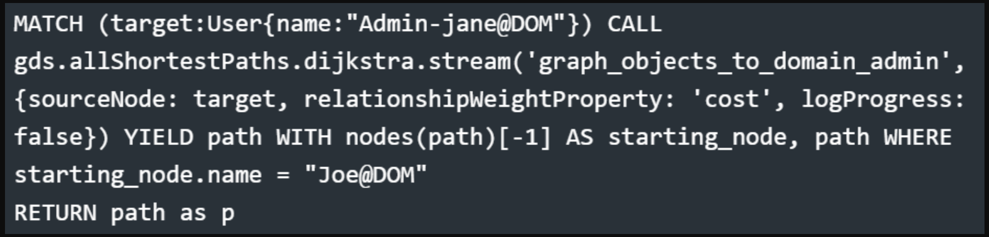
- Install/Load Graph Data Science (GDS) plugin for Neo4j (*)

- Create a graph projection



```
CALL gds.graph.project.cypher('graph_objects_to_domain_admin', 'MATCH (n)
RETURN id(n) AS id', 'MATCH (n)-[r:$properties$]->(m) RETURN id(m) as
source, id(n) AS target, r.cost as cost', {validateRelationships: false})
```

- Use **Dijkstra algorithm** to query path with lower cost

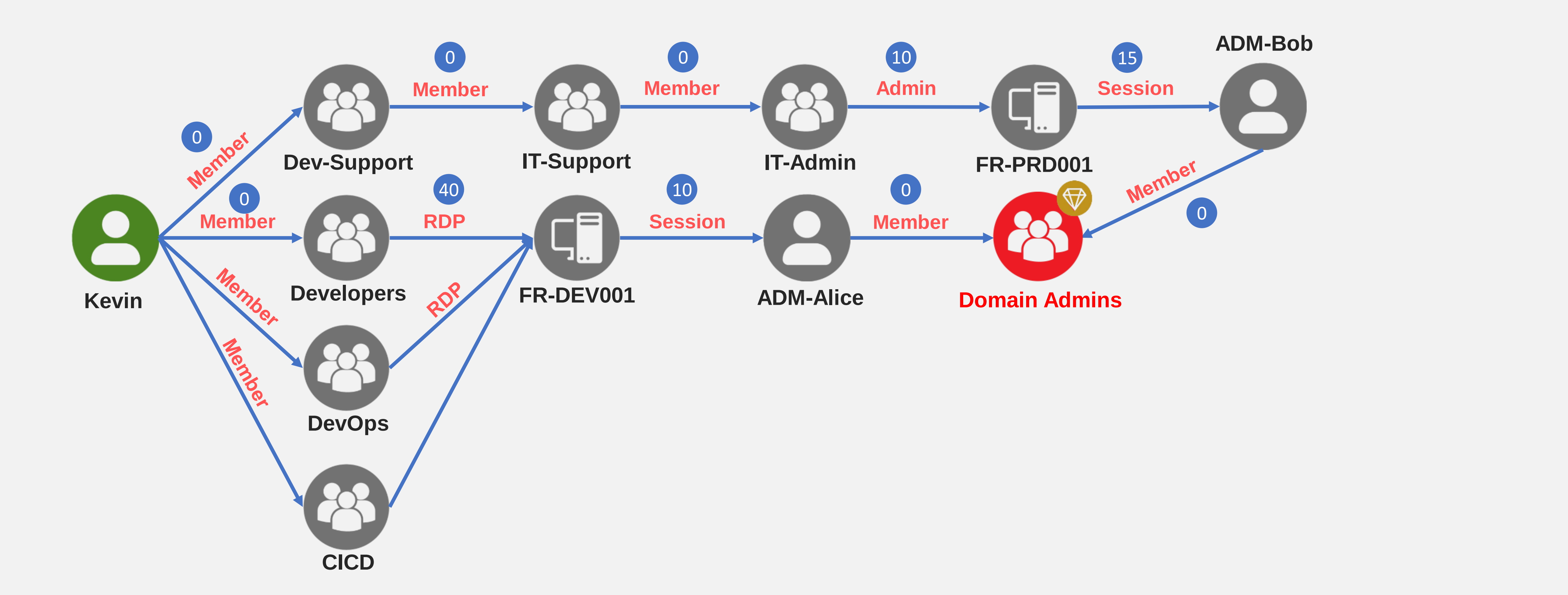


```
MATCH (target:User{name:"Admin-jane@DOM"}) CALL
gds.allShortestPaths.dijkstra.stream('graph_objects_to_domain_admin',
{sourceNode: target, relationshipWeightProperty: 'cost', logProgress:
false}) YIELD path WITH nodes(path)[-1] AS starting_node, path WHERE
starting_node.name = "Joe@DOM"
RETURN path as p
```

(*) Installed by default if you create your Bloodhound environment with github.com/Tanguy-Boisset/bloodhound-automation

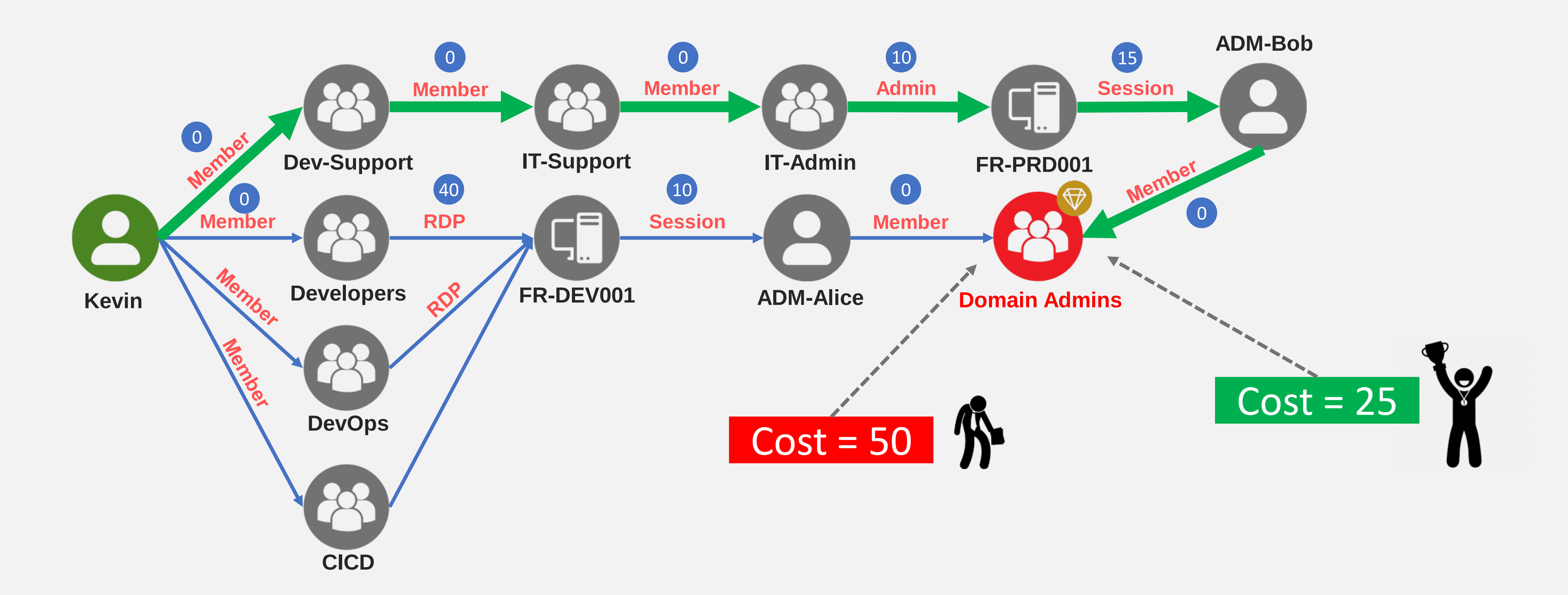
Innovations

- Smartest path (more hops but way easier to exploit)



Innovations

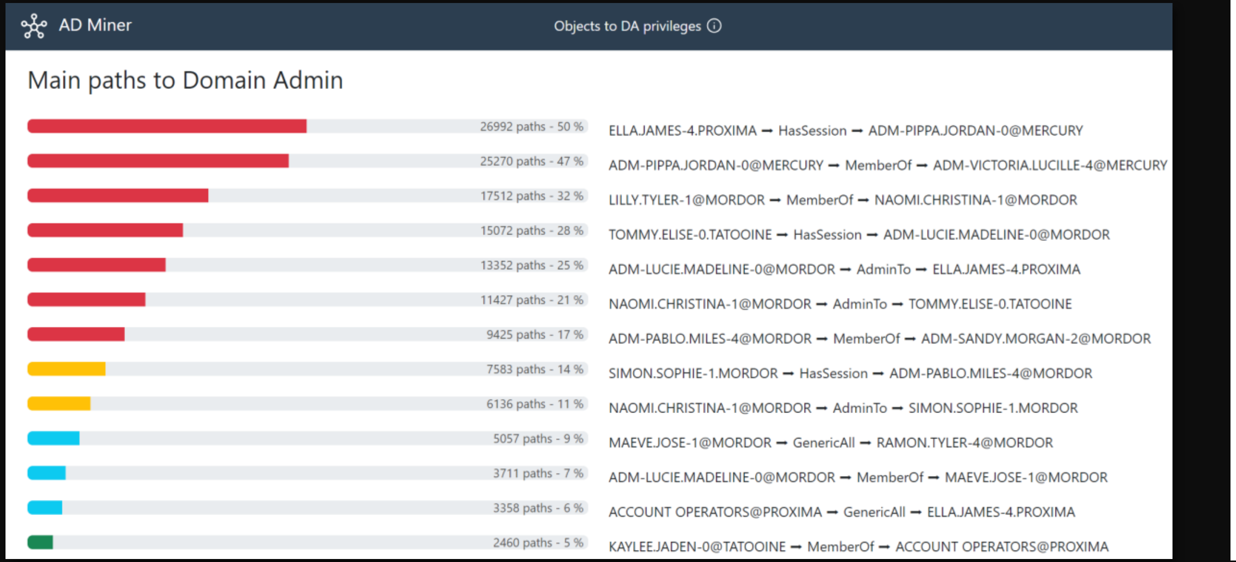
- Smartest path (more hops but way easier to exploit)



Things that BH can not do out of the box

- Computing choke-points:
  - i.e., issues that are top contributors to attack paths
  - Fairly easy to do with basic data analytics
  - Shows mitigation quick wins

- Evolution over multiple extractions

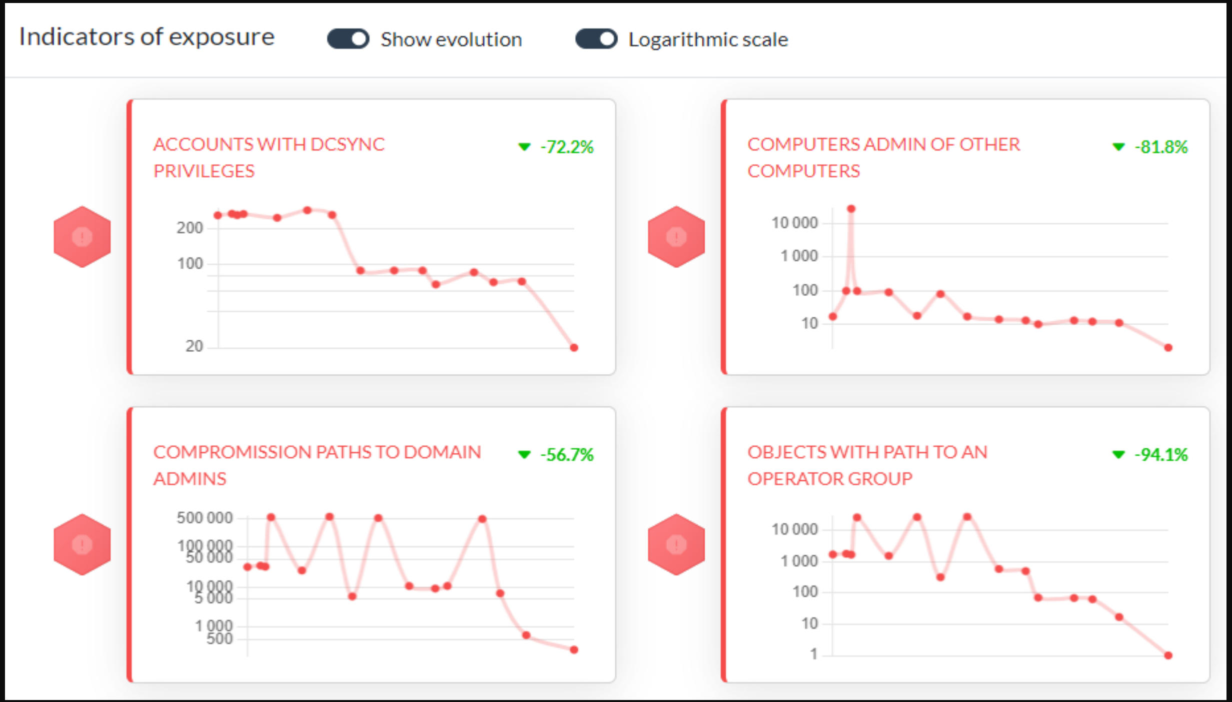


AD Miner

Objects to DA privileges ⓘ

Main paths to Domain Admin

26992 paths - 50 %	ELLA.JAMES-4.PROXIMA ➡ HasSession ➡ ADM-PIPPA.JORDAN-0@MERCURY
25270 paths - 47 %	ADM-PIPPA.JORDAN-0@MERCURY ➡ MemberOf ➡ ADM-VICTORIA.LUCILLE-4@MERCURY
17512 paths - 32 %	LILLY.TYLER-1@MORDOR ➡ MemberOf ➡ NAOMI.CHRISTINA-1@MORDOR
15072 paths - 28 %	TOMMY.ELISE-0.TATOOINE ➡ HasSession ➡ ADM-LUCIE.MADELINE-0@MORDOR
13352 paths - 25 %	ADM-LUCIE.MADELINE-0@MORDOR ➡ AdminTo ➡ ELLA.JAMES-4.PROXIMA
11427 paths - 21 %	NAOMI.CHRISTINA-1@MORDOR ➡ AdminTo ➡ TOMMY.ELISE-0.TATOOINE
9425 paths - 17 %	ADM-PABLO.MILES-4@MORDOR ➡ MemberOf ➡ ADM-SANDY.MORGAN-2@MORDOR
7583 paths - 14 %	SIMON.SOPHIE-1.MORDOR ➡ HasSession ➡ ADM-PABLO.MILES-4@MORDOR
6136 paths - 11 %	NAOMI.CHRISTINA-1@MORDOR ➡ AdminTo ➡ SIMON.SOPHIE-1.MORDOR
5057 paths - 9 %	MAEVE.JOSE-1@MORDOR ➡ GenericAll ➡ RAMON.TYLER-4@MORDOR
3711 paths - 7 %	ADM-LUCIE.MADELINE-0@MORDOR ➡ MemberOf ➡ MAEVE.JOSE-1@MORDOR
3358 paths - 6 %	ACCOUNT OPERATORS@PROXIMA ➡ GenericAll ➡ ELLA.JAMES-4.PROXIMA
2460 paths - 5 %	KAYLEE.JADEN-0@TATOOINE ➡ MemberOf ➡ ACCOUNT OPERATORS@PROXIMA



Indicators of exposure ● Show evolution ● Logarithmic scale

ACCOUNTS WITH DCSYNC PRIVILEGES ▼ -72.2%

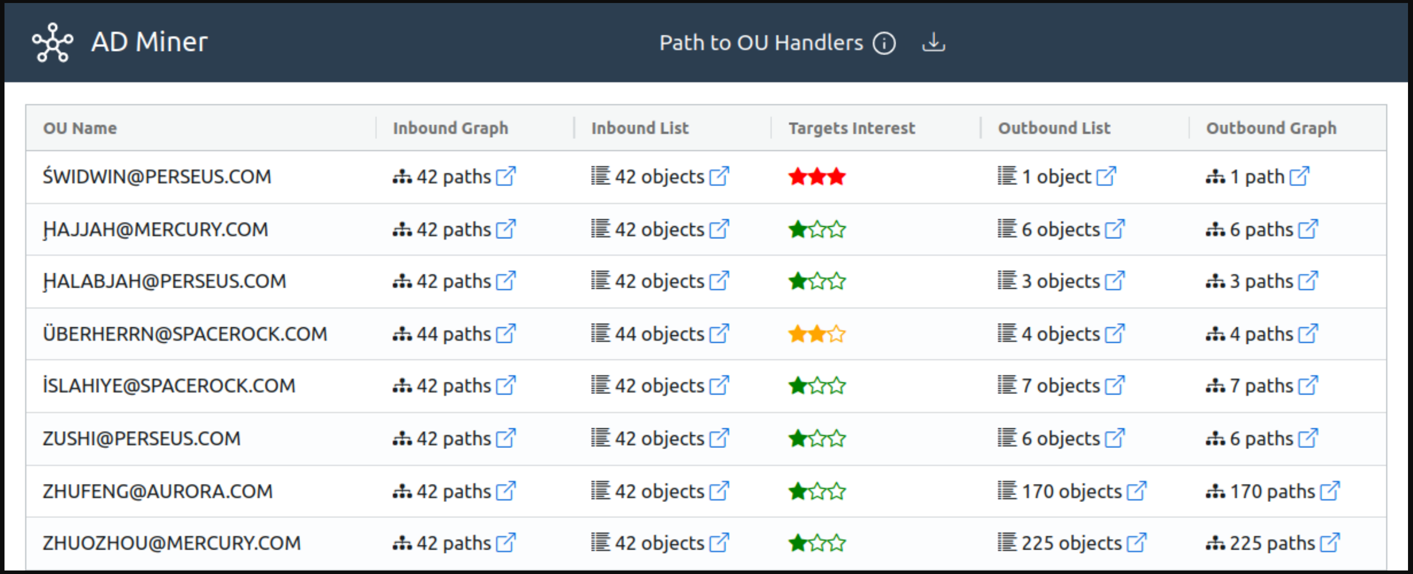
COMPUTERS ADMIN OF OTHER COMPUTERS ▼ -81.8%

COMPROMISSION PATHS TO DOMAIN ADMINS ▼ -56.7%

OBJECTS WITH PATH TO AN OPERATOR GROUP ▼ -94.1%

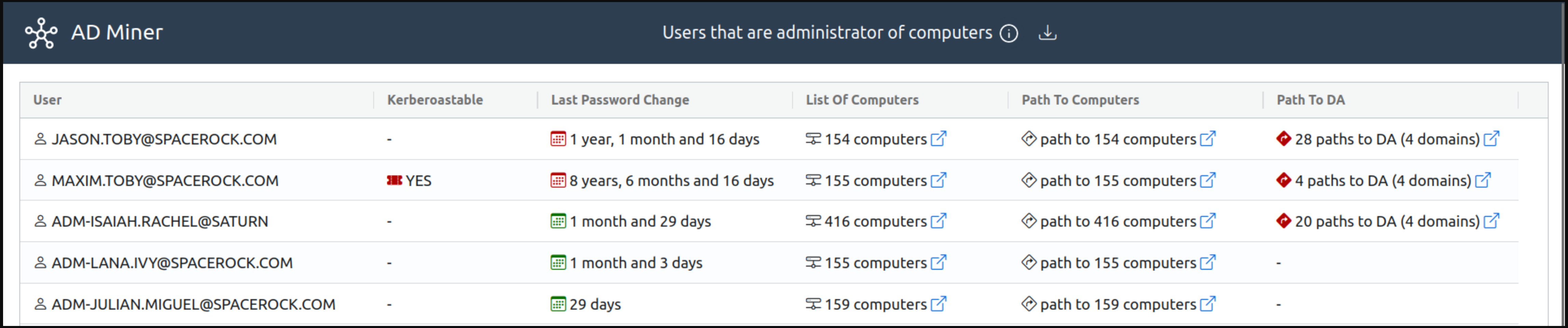
Things that BH can not do out of the box

- Show deviant objects within comprehensible lists



AD Miner — Path to OU Handlers

OU Name	Inbound Graph	Inbound List	Targets Interest	Outbound List	Outbound Graph
ŚWIDWIN@PERSEUS.COM	42 paths	42 objects	★★★	1 object	1 path
ḤAJJAH@MERCURY.COM	42 paths	42 objects	★☆☆	6 objects	6 paths
ḤALABJAH@PERSEUS.COM	42 paths	42 objects	★☆☆	3 objects	3 paths
ÜBERHERRN@SPACEROCK.COM	44 paths	44 objects	★★☆	4 objects	4 paths
İSLAHIYE@SPACEROCK.COM	42 paths	42 objects	★☆☆	7 objects	7 paths
ZUSHI@PERSEUS.COM	42 paths	42 objects	★☆☆	6 objects	6 paths
ZHUFENG@AURORA.COM	42 paths	42 objects	★☆☆	170 objects	170 paths
ZHUOZHOU@MERCURY.COM	42 paths	42 objects	★☆☆	225 objects	225 paths



AD Miner — Users that are administrator of computers

User	Kerberoastable	Last Password Change	List Of Computers	Path To Computers	Path To DA
JASON.TOBY@SPACEROCK.COM	-	1 year, 1 month and 16 days	154 computers	path to 154 computers	28 paths to DA (4 domains)
MAXIM.TOBY@SPACEROCK.COM	YES	8 years, 6 months and 16 days	155 computers	path to 155 computers	4 paths to DA (4 domains)
ADM-ISAIAH.RACHEL@SATURN	-	1 month and 29 days	416 computers	path to 416 computers	20 paths to DA (4 domains)
ADM-LANA.IVY@SPACEROCK.COM	-	1 month and 3 days	155 computers	path to 155 computers	-
ADM-JULIAN.MIGUEL@SPACEROCK.COM	-	29 days	159 computers	path to 159 computers	-

Demo

Links

github.com/Mazars-Tech/AD_Miner/

```
> $   pipx install 'git+https://github.com/Mazars-Tech/AD_Miner.git'
```

Q&A

Questions ?