Secure Information and Resource Sharing in Cloud Infrastructure as a Service

Dissertation Defense

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Presentation Outline

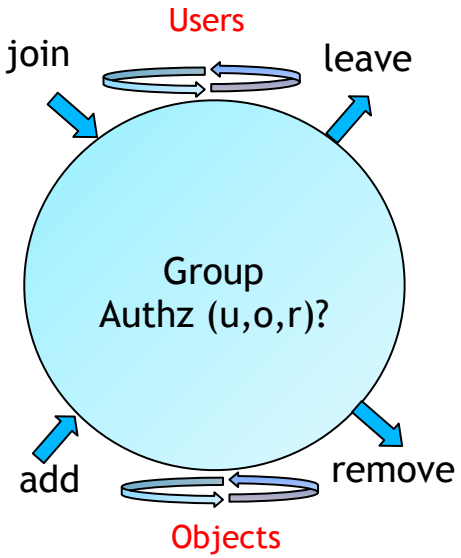
- Introduction
- Background and related work
- Secure Isolated Domain (SID) Model
- SID Model in OpenStack
- SID Model in AWS
- SID Model in Azure
- Conclusion

Introduction

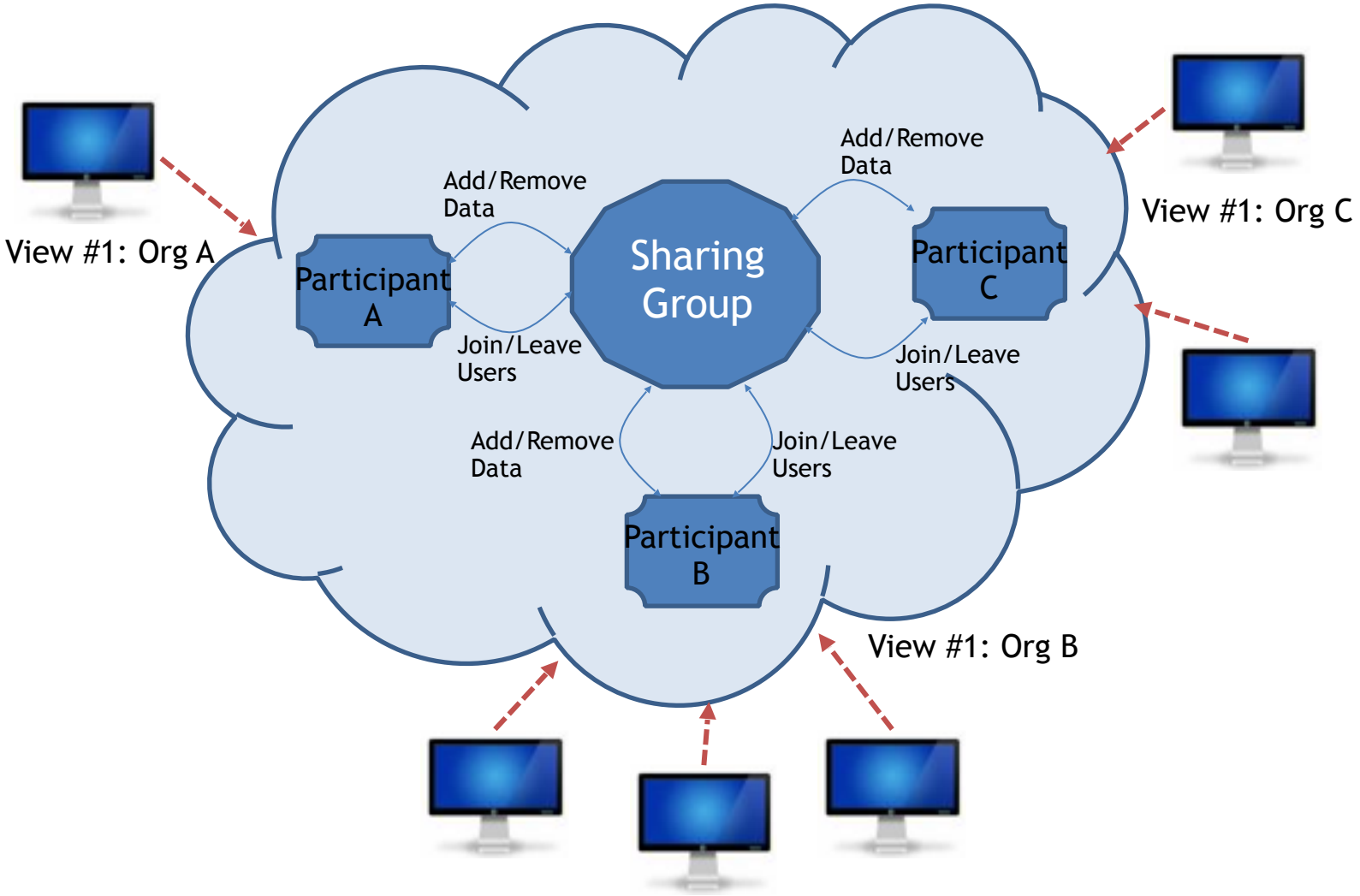
- Traditional Cyber Collaboration
  - Subscription services
  - Limitations
    - Organizations Sharing information through subscription.
    - Organizations are not actively participating in analyzing and processing the cyber information they submit.
    - Organizations don't directly interact with each other on sharing activities.
- Cloud IaaS Advantages for Cyber Incident Sharing
  - Virtualized resources
  - Operational efficiency
    - Light-weight and agile
    - Rapid deployment and configuration
    - Dynamic scaling
    - Self-service

Background/Related Work

- Group-Centric Sharing
  - Sharing for a specific purpose or mission
    - E.g. Collaboration in joint product design.
    - E.g. Inter-organizational collaboration.
  - Brings users & objects together in a group
    - Secure Meeting Room



Sharing Model in Cloud IaaS



Refererence: Ram Krishnan, Ravi Sandhu, Jianwei Niu and William Winsborough, Towards a framework for group-centric secure collaboration, In Proceedings 5th IEEE International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom), 2009.

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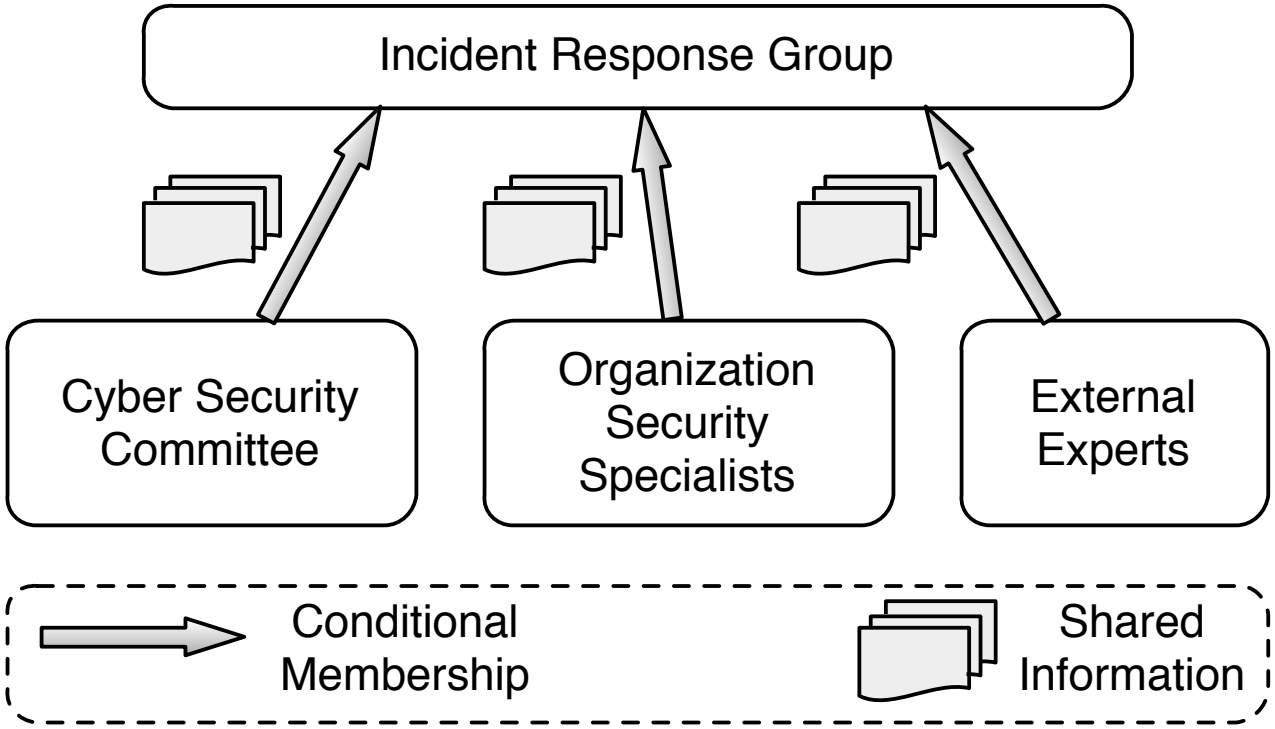
Background/Related Work

- Community Cyber Incident Response



Adapted from: Ravi Sandhu, Khalid Zaman Bijon, Xin Jin and Ram Krishnan, RT-based administrative models for community cyber security information sharing. In Proceedings of the 6th IEEE International Workshop on Trusted Collaboration (TrustCol), 2011.

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Problem and Statement

- Problem Statement

  There is lack of access control models for information and resource sharing within collaborative groups in IaaS cloud platforms.

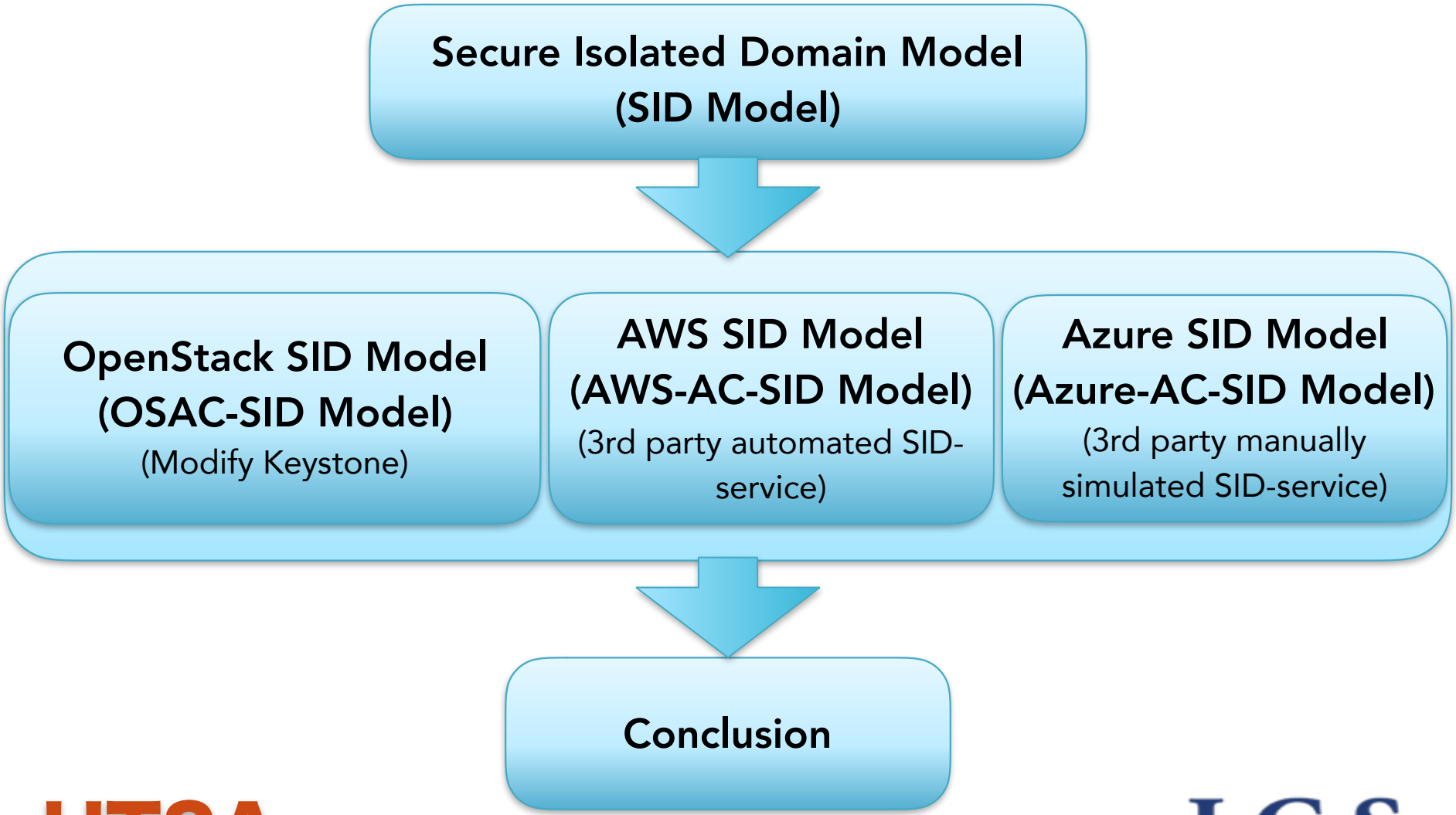
- Thesis Statement

  Secure sharing information and resources in IaaS cloud can be achieved by a common access control model that is enforceable in the currently dominant cloud IaaS platforms (viz., OpenStack, AWS and Azure).

Scope

- Sharing models — sharing amongst a set of organizations
- Cloud deployment models — a single public or community cloud
- Cloud service models — focus on Infrastructure as a Service (IaaS)
- Scenario — Cyber Incident Response

Outline


Secure Isolated Domain Model
(SID Model)
OpenStack SID Model
(OSAC-SID Model)
(Modify Keystone)
AWS SID Model
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(3rd party automated SID-service)
Azure SID Model
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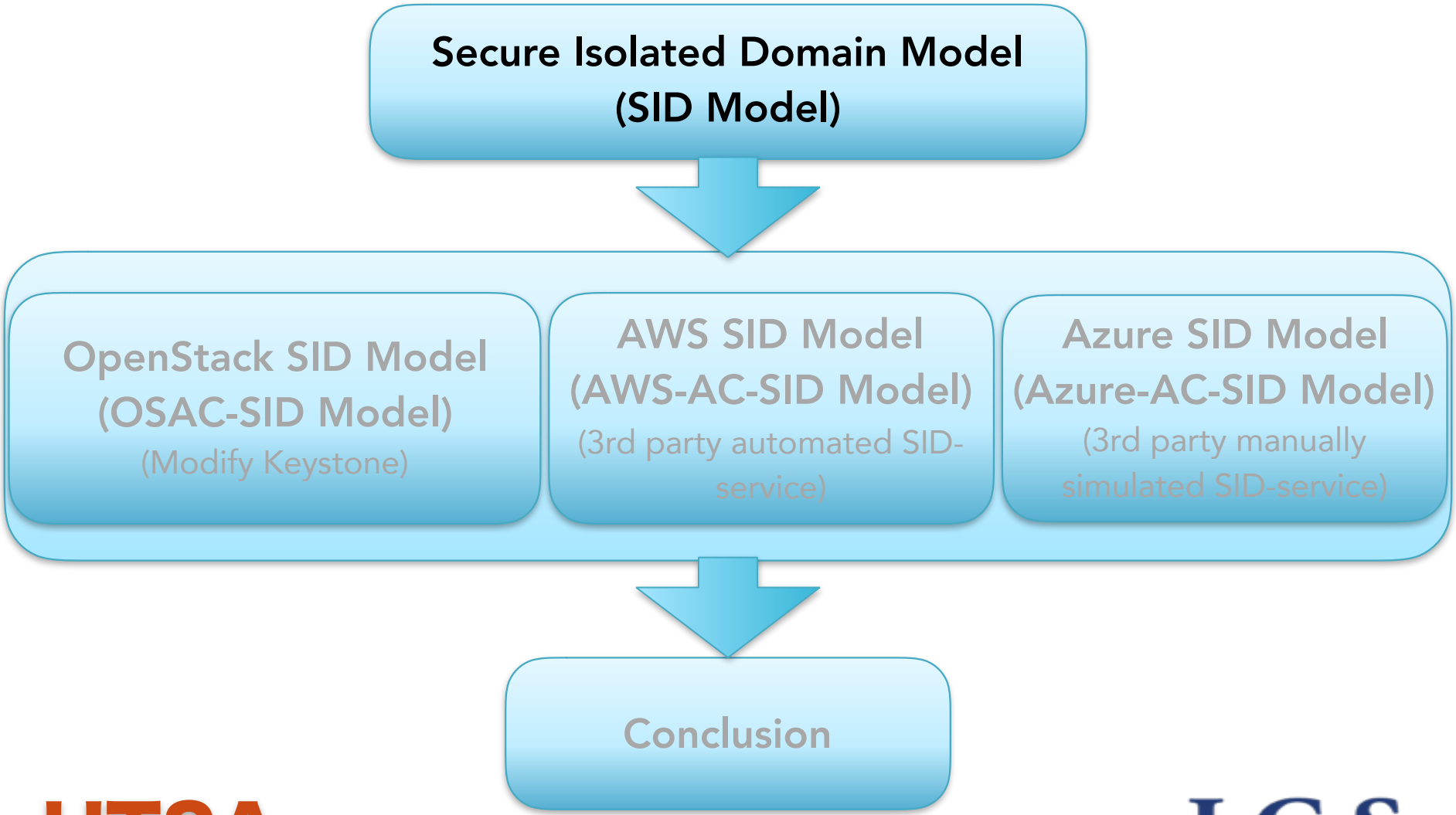
(3rd party manually simulated SID-service)
Conclusion

Outline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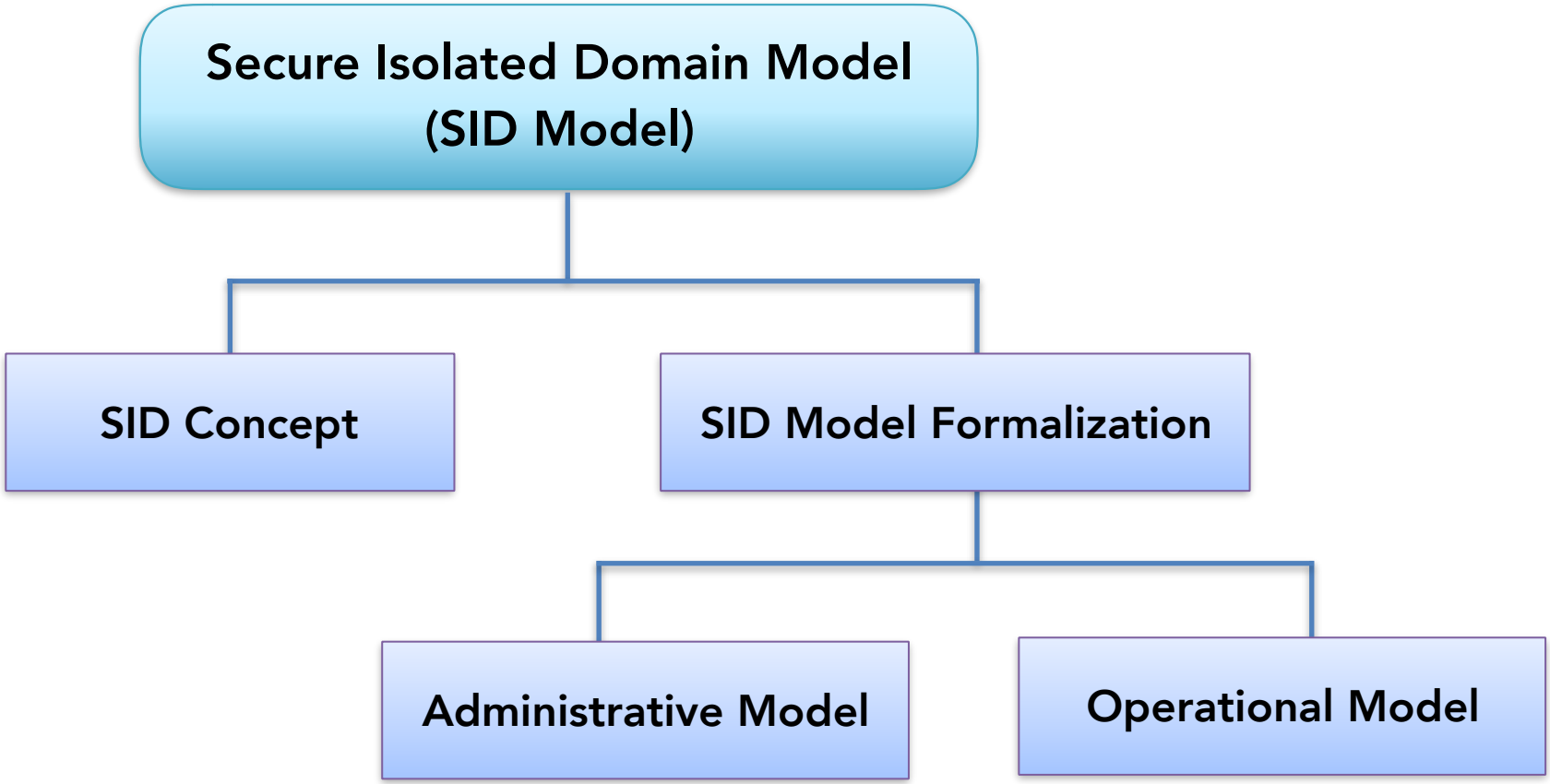
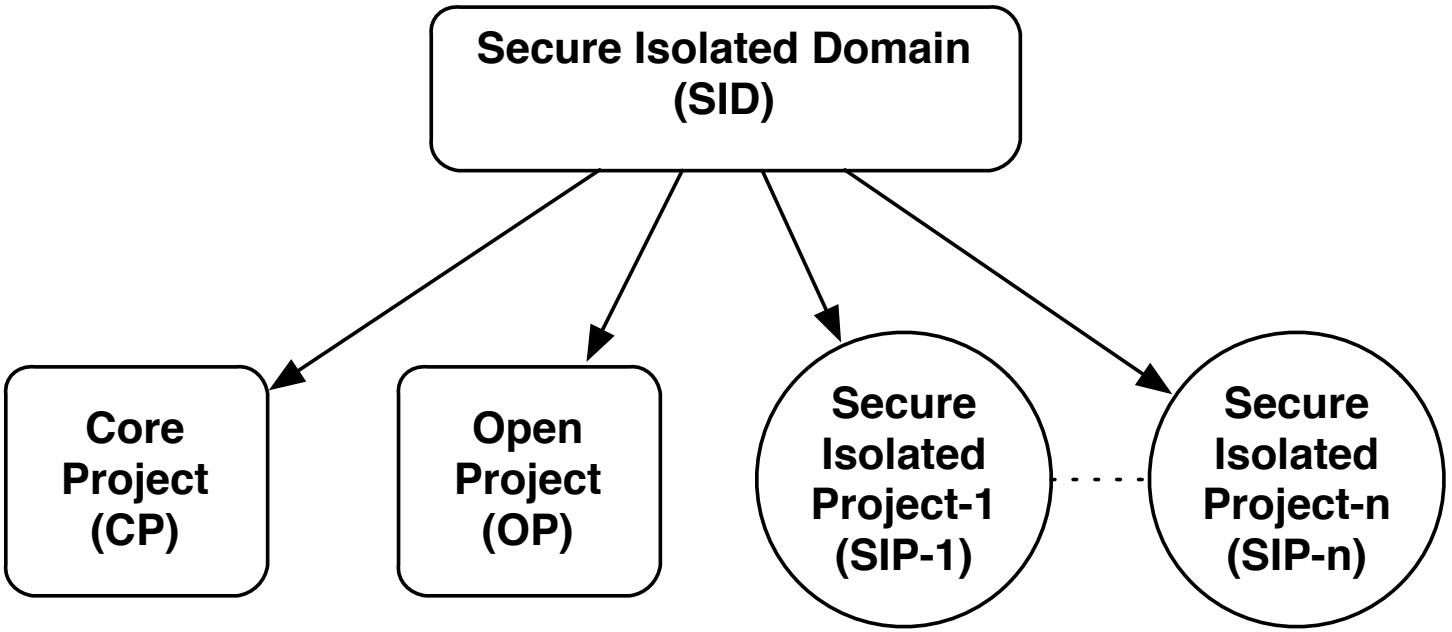
SID Model


Secure Isolated Domain Model
(SID Model)
SID Concept
SID Model Formalization
Administrative Model
Operational Model

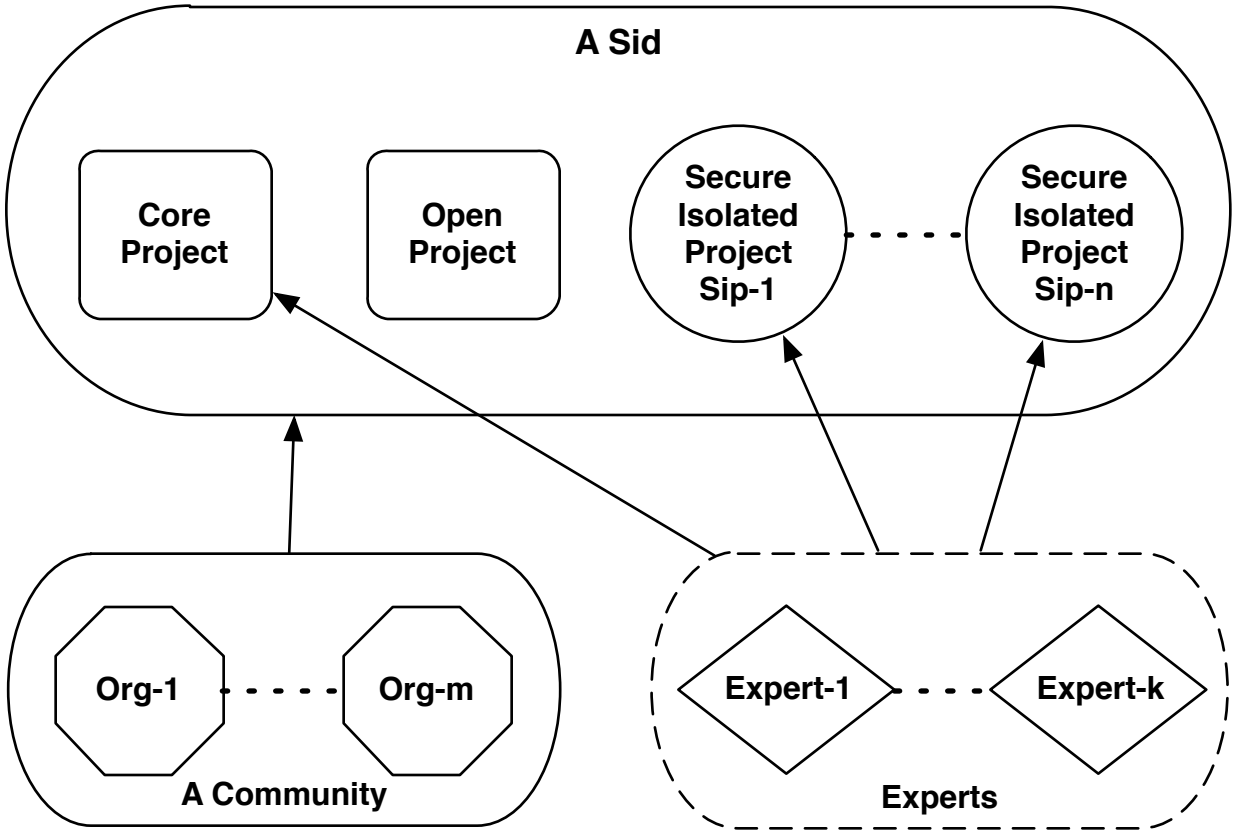
SID Concept

- Secure Isolated Domain (SID)

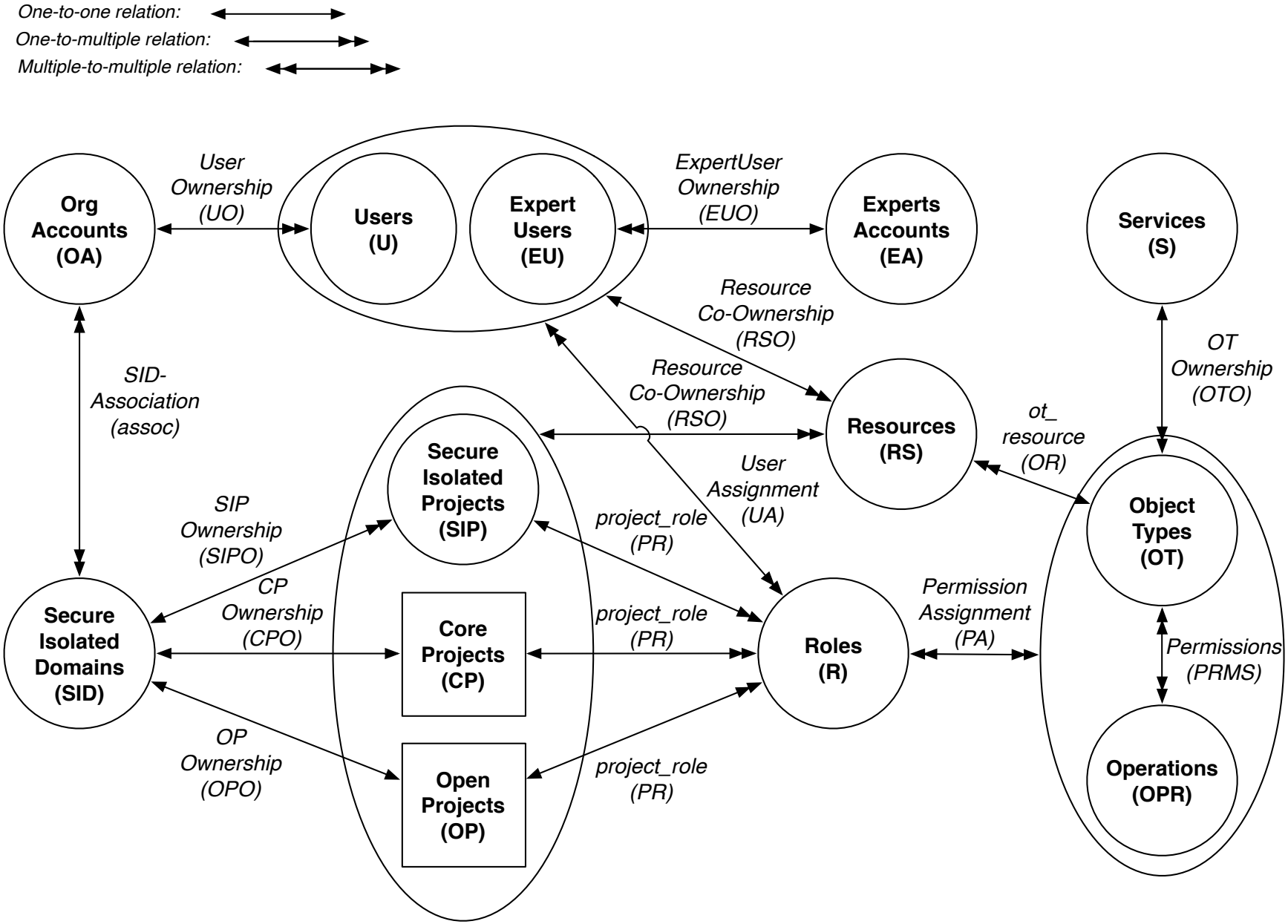


SID Concept

- A Community with a Sid



SID Model


One-to-one relation:
One-to-multiple relation:
Multiple-to-multiple relation:
Org Accounts (OA)
User Ownership (UO)
Users (U)
Expert Users (EU)
ExpertUser Ownership (EUO)
Experts Accounts (EA)
Services (S)
Resource Co-Ownership (RSO)
OT Ownership (OTO)
SID-Association (assoc)
Resource Co-Ownership (RSO)
Resources (RS)
ot_ resource (OR)
User Assignment (UA)
Secure Isolated Projects (SIP)
SIP Ownership (SIPO)
project_role (PR)
Object Types (OT)
CP Ownership (CPO)
Secure Isolated Domains (SID)
Core Projects (CP)
project_role (PR)
Roles (R)
Permission Assignment (PA)
Permissions (PRMS)
OP Ownership (OPO)
Open Projects (OP)
project_role (PR)
Operations (OPR)

SID Administrative Model

- SidCreate/SidDelete
  - An admin user representing uSet creates/deletes a sid
- SipCreate/SipDelete
  - An admin user representing uSet creates/deletes a sip
- UserAdd/UserRemove
  - Admin users add/remove a user from his home domain to a cp/op/sip
- EUserAdd/EUserRemove
  - Admin users add/remove an expert user to a cp/sip

SID Administrative Model formalization

Operation	Authorization Requirement	Update
SidCreate(adminu, uSet, sid) */* An admin user representing uSet creates a sid */*	adminu $\in$ *uSet* $\wedge$ adminu $\in$ U $\wedge$ sid $\notin$ SID	SID′ = SID $\cup$ {sid}; assoc(sid) = $\bigcup_{adminu \in uSet}$ UO(adminu); CP′ = CP $\cup$ {cp}; CPO(cp) = sid; OP′ = OP $\cup$ {op}; OPO(op) = sid; UA′ = (uSet, *SIDadmin*) $\cup$ UA; PR′ = PR $\cup$ {(cp, *SIDadmin*), (op, *SIDadmin*)}.
SidDelete(adminu, uSet, sid) */* An admin user representing uSet deletes the sid*/*	adminu $\in$ *uSet* $\wedge$ adminu $\in$ U $\wedge$ (adminu, *SIDadmin*) $\in$ UA $\wedge$ assoc(sid) = $\bigcup_{adminu \in uSet}$ UO(adminu) $\wedge$ sid $\in$ SID	SID′ = SID - {sid}; assoc(sid) = NULL; CP′ = CP - {cp}; CPO(cp) = NULL; OP′ = OP - {op}; OPO(op) = NULL; UA′ = UA - (uSet, *SIDadmin*); PR′ = PR - {(cp, *SIDadmin*), (op, *SIDadmin*)}; if $\exists$ u $\in$ (U $\cup$ EU).((u, *SIDmember*) $\in$ UA), then UA′ = UA - (u, *SIDmember*); if $\exists$ sip $\in$ SIP.(SIPO(sip) = sid), then SIP′ = SIP - sip $\wedge$ PR′ = PR - {(sip, *SIDadmin*), (sip, *SIDmember*)}.

SID Administrative Model formalization

Operation	Authorization Requirement	Update
SipCreate(adminu, sip, sid) */* An admin user representing uSet creates a sip */*	adminu ∈ U ∧ (adminu, *SIDadmin*) ∈ UA ∧ UO(adminu) ∈ assoc(sid) ∧ sip ∉ SIP	SIP′ = SIP ∪ {sip}; SIPO(sip) = sid; PR′ = PR ∪ {(sip, *SIDadmin*)}.
SipDelete(adminu, sip, sid) */* An admin user representing uSet deletes a sip*/*	adminu ∈ U ∧ (adminu, *SIDadmin*) ∈ UA ∧ UO(adminu) ∈ assoc(sid) ∧ SIPO(sip) = sid	SIP′ = SIP - {sip}; SIPO(sip) = NULL; PR′ = PR - {(sip, *SIDadmin*)}.
UserAdd(adminu, u, p, sid) */* Admin users add a user from his home domain to a cp, op or sip */*	adminu ∈ U ∧ (adminu, *SIDadmin*) ∈ UA ∧ (p, *SIDadmin*) ∈ PR ∧ u ∈ U ∧ UO(u) = UO(adminu) ∧ p ∈ (CP ∪ OP ∪ SIP) ∧ (CPO(p) = sid ∨ OPO(p) = sid ∨ SIP(p) = sid)	UA′ = UA ∪ {(u, *SIDmember*)}.
UserRemove(adminu, u, p, sid) */* Admin users remove a user from a cp, op or sip */*	adminu ∈ U ∧ (adminu, *SIDadmin*) ∈ UA ∧ (p, *SIDadmin*) ∈ PR ∧ u ∈ U ∧ UO(u) = UO(adminu) ∧ p ∈ (CP ∪ OP ∪ SIP) ∧ (CPO(p) = sid ∨ OPO(p) = sid ∨ SIP(p) = sid) ∧ (u, *SIDmember*) ∈ UA ∧ (p, *SIDmember*) ∈ PR	UA′ = UA - {(u, *SIDmember*)}.
EUserAdd(adminu, eu, p, sid) */* Admin users add an expert user to a cp or sip */*	adminu ∈ U ∧ (adminu, *SIDadmin*) ∈ UA ∧ (p, *SIDadmin*) ∈ PR ∧ eu ∈ EU ∧ p ∈ (CP ∪ SIP) ∧ (CPO(p) = sid ∨ SIPO(p) = sid)	UA′ = UA ∪ {(eu, *SIDmember*)}.
EUserRemove(adminu, eu, p, sid) */* Admin users remove an expert user from a cp or sip */*	adminu ∈ U ∧ (adminu, *SIDadmin*) ∈ UA ∧ (p, *SIDadmin*) ∈ PR ∧ eu ∈ EU ∧ p ∈ (CP ∪ SIP) ∧ (CPO(p) = sid ∨ SIPO(p) = sid) ∧ (eu, *SIDmember*) ∈ UA ∧ (p, *SIDmember*) ∈ PR	UA′ = UA - {(eu, *SIDmember*)}.

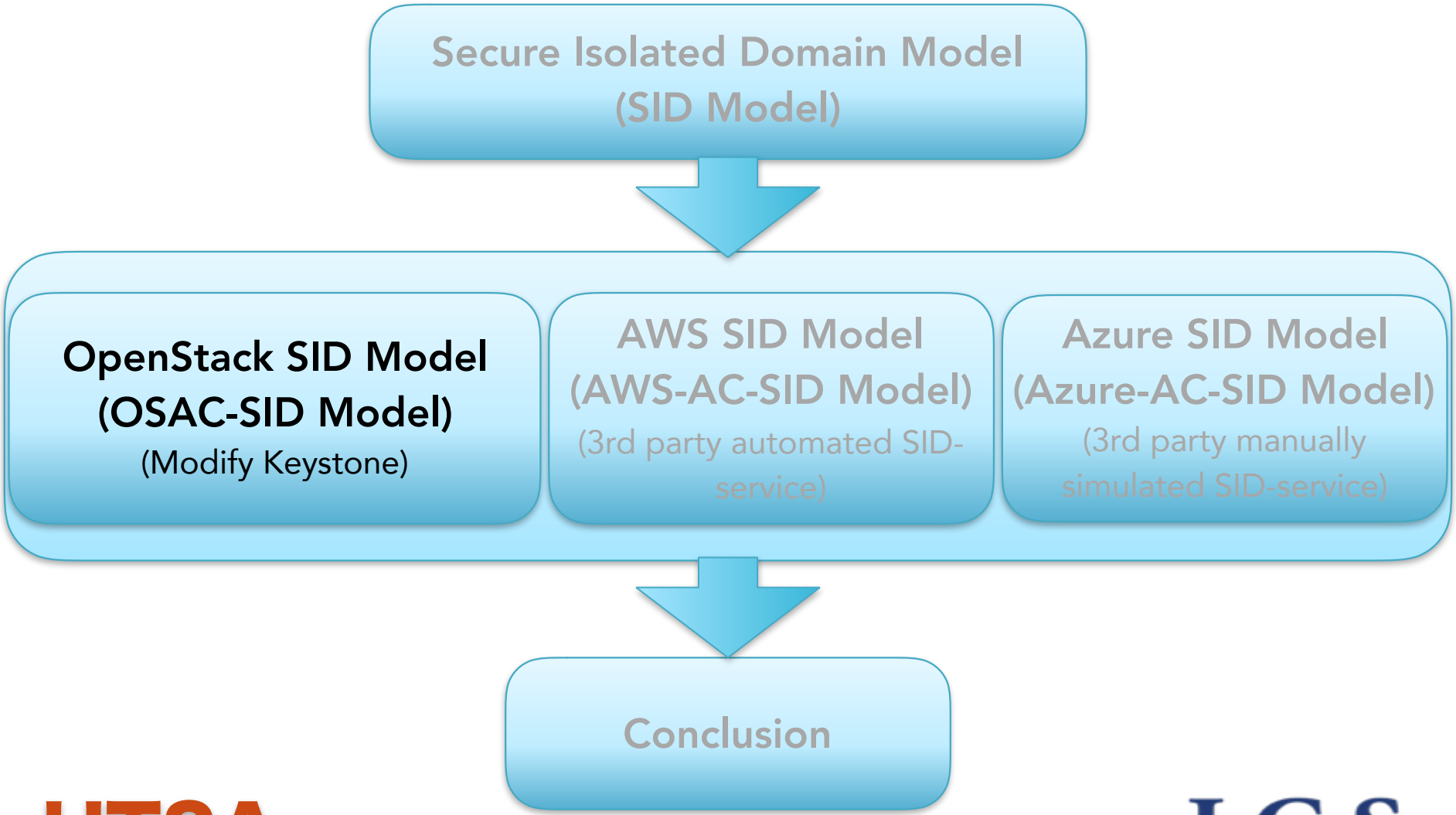
SID Operational Model formalization

- CreateVM/DeleteVM
  - A user creates/deletes a vm
- CreateSContainer/DeleteSContainer
  - A user creates/deletes a storage container
- CreateObject/DeleteObject
  - A user creates/deletes a storage container object

SID Operational Model

Operation	Authorization Requirement	Update
CreateVM(vm, p, u) */* A user creates a vm */*	$vm \notin RS \wedge p \in (CP \cup OP \cup SIP) \wedge u \in U \wedge \exists (perms, r) \in PA.(perms = (vm, create) \wedge (p, r) \in PR \wedge (u, (p, r)) \in UA)$	$RS' = RS \cup \{vm\}$; $RSO' = RSO \cup \{(vm, (p, u))\}$; $OR(vm) = VM$.
DeleteVM(vm, p, u) */* A user deletes a vm */*	$vm \in RS \wedge RSO(vm) = \{(p, u)\} \wedge p \in (CP \cup OP \cup SIP) \wedge u \in U \wedge \exists (perms, r) \in PA.(perms = (vm, delete) \wedge (p, r) \in PR \wedge (u, (p, r)) \in UA$	$RS' = RS - \{vm\}$; $RSO' = RSO - \{(vm, (p, u))\}$; $vm = NULL$.
CreateSContainer(sc, p, u) */* A user creates a storage container */*	$sc \notin RS \wedge p \in (CP \cup OP \cup SIP) \wedge u \in U \wedge \exists (perms, r) \in PA.(perms = (sc, create) \wedge (p, r) \in PR \wedge (u, (p, r)) \in UA)$	$RS' = RS \cup \{sc\}$; $RSO' = RSO \cup \{(sc, (p, u))\}$; $OR(sc) = SC$.
DeleteSContainer(sc, p, u) */* A user deletes a storage container */*	$sc \in RS \wedge RSO(sc) = \{(p, u)\} \wedge p \in (CP \cup OP \cup SIP) \wedge u \in U \wedge \exists (perms, r) \in PA.(perms = (sc, delete) \wedge (p, r) \in PR \wedge (u, (p, r)) \in UA$	$RS' = RS - \{sc\}$; $RSO' = RSO - \{(sc, (p, u))\}$; $sc = NULL$.
CreateObject(co, sc, p, u) */* A user creates a storage container object */*	$co \notin RS \wedge sc \in RS \wedge p \in (CP \cup OP \cup SIP) \wedge u \in U \wedge RSO(sc) = (p, u) \wedge \exists (perms, r) \in PA.(perms = (co, create) \wedge (p, r) \in PR \wedge (u, (p, r)) \in UA)$	$RS' = RS \cup \{co\}$; $RSO' = RSO \cup \{(co, (p, u))\}$; $OR(co) = CO$.
DeleteObject(co, sc, p, u) */* A user delete a storage container object */*	$co \in RS \wedge RSO(co) = \{(p, u)\} \wedge sc \in RS \wedge p \in (CP \cup OP \cup SIP) \wedge u \in U \wedge RSO(sc) = (p, u) \wedge \exists (perms, r) \in PA.(perms = (co, create) \wedge (p, r) \in PR \wedge (u, (p, r)) \in UA)$	$RS' = RS - \{co\}$; $RSO' = RSO - \{(co, (p, u))\}$; $co = NULL$.

Outline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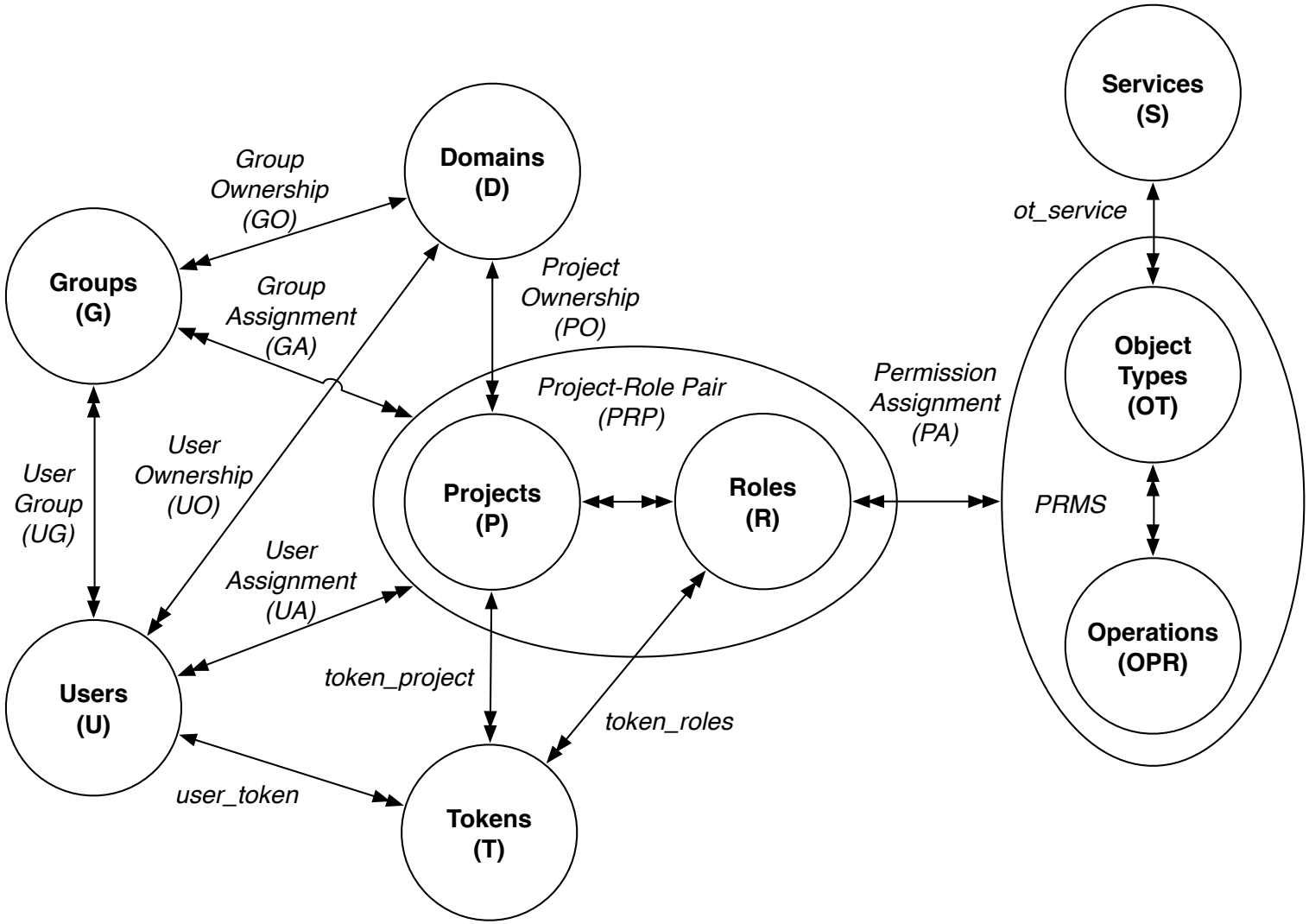
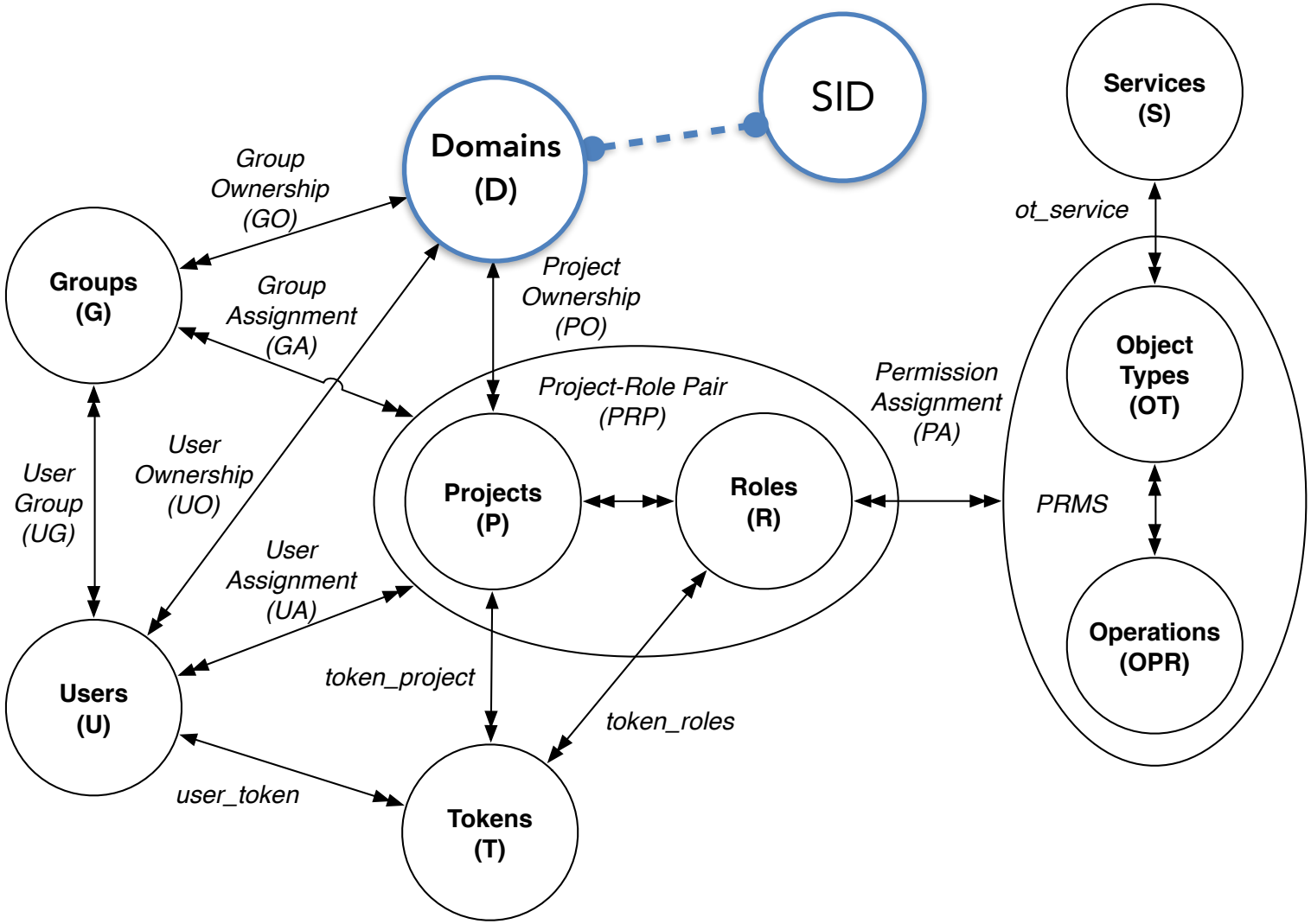
OpenStack Access Control (OSAC) Model



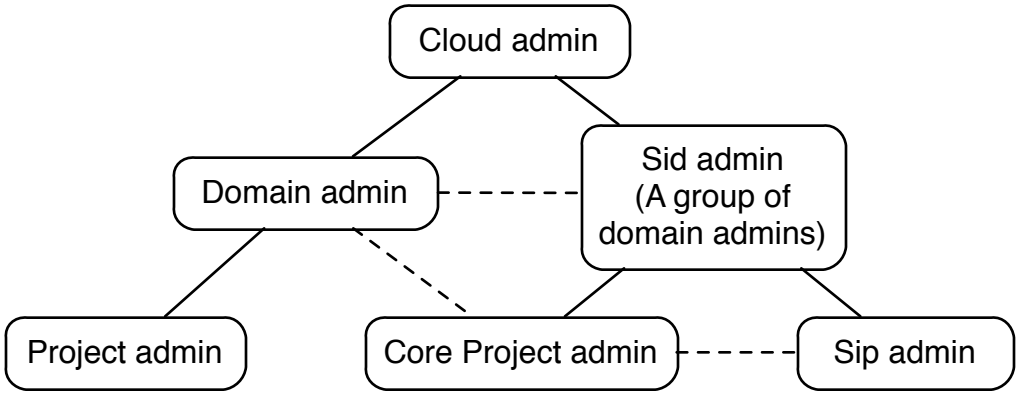
Reference: Bo Tang and Ravi Sandhu, Extending OpenStack access control with domain trust. In Proceedings 8th International Conference on Network and System Security (NSS), 2014.

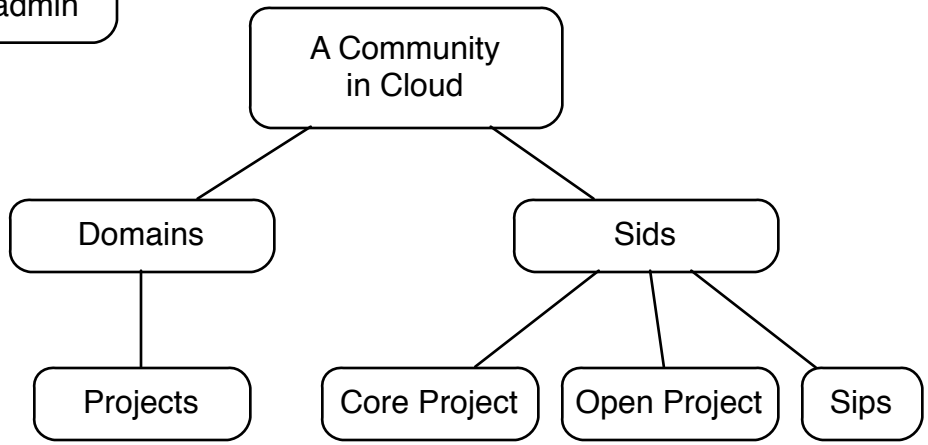
OSAC Model extends with SID



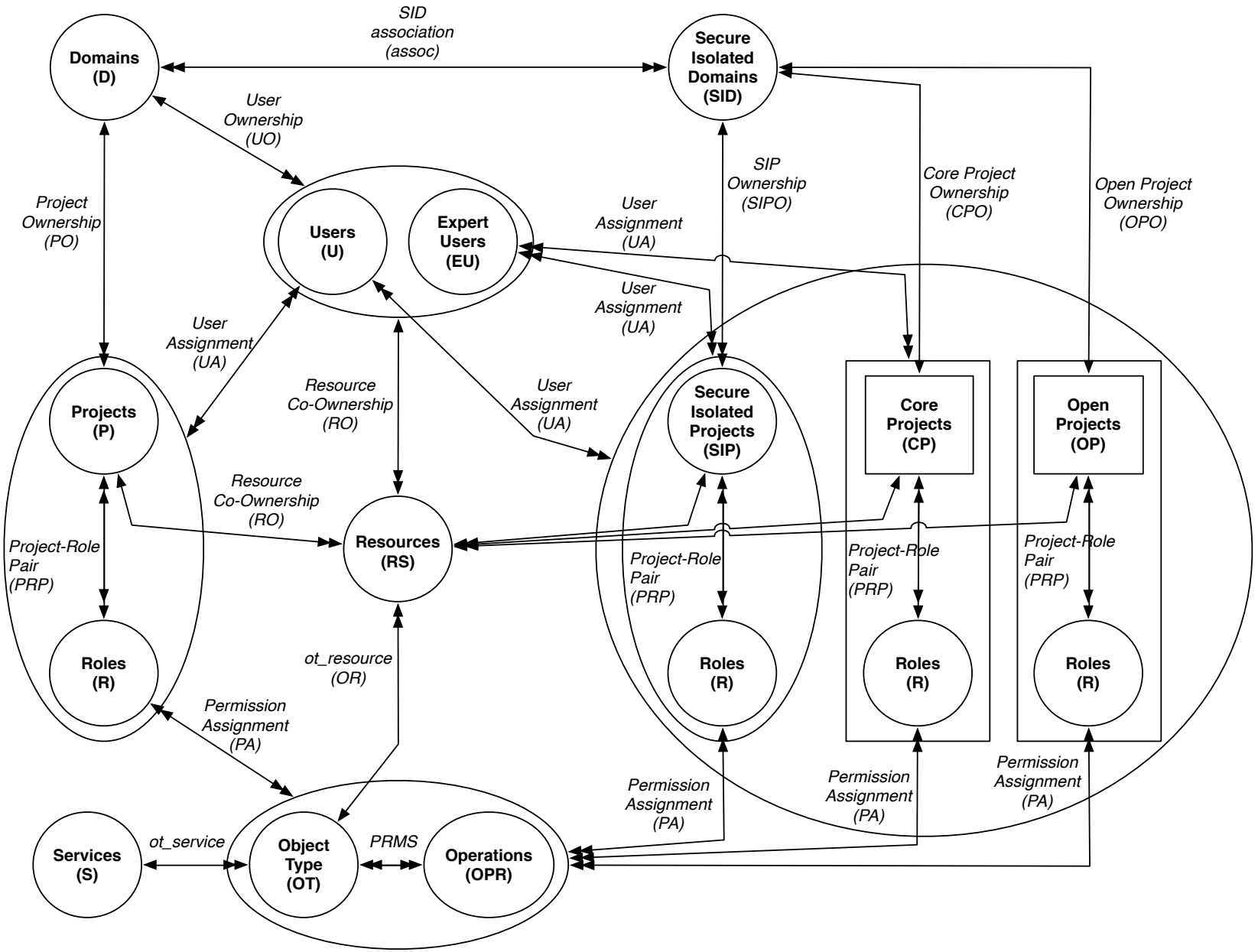
OSAC-SID Model

- Sid admins and cloud resource division

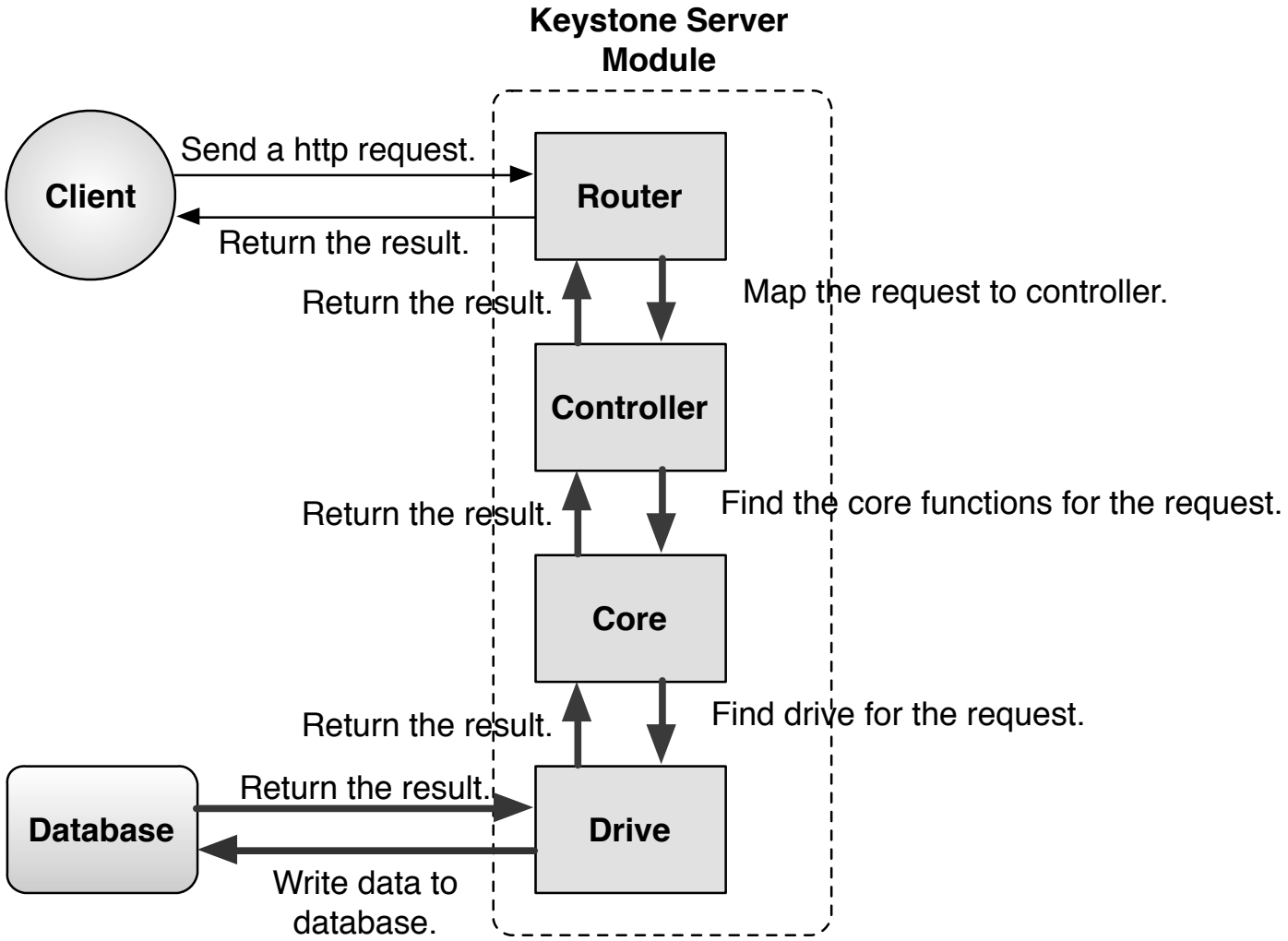




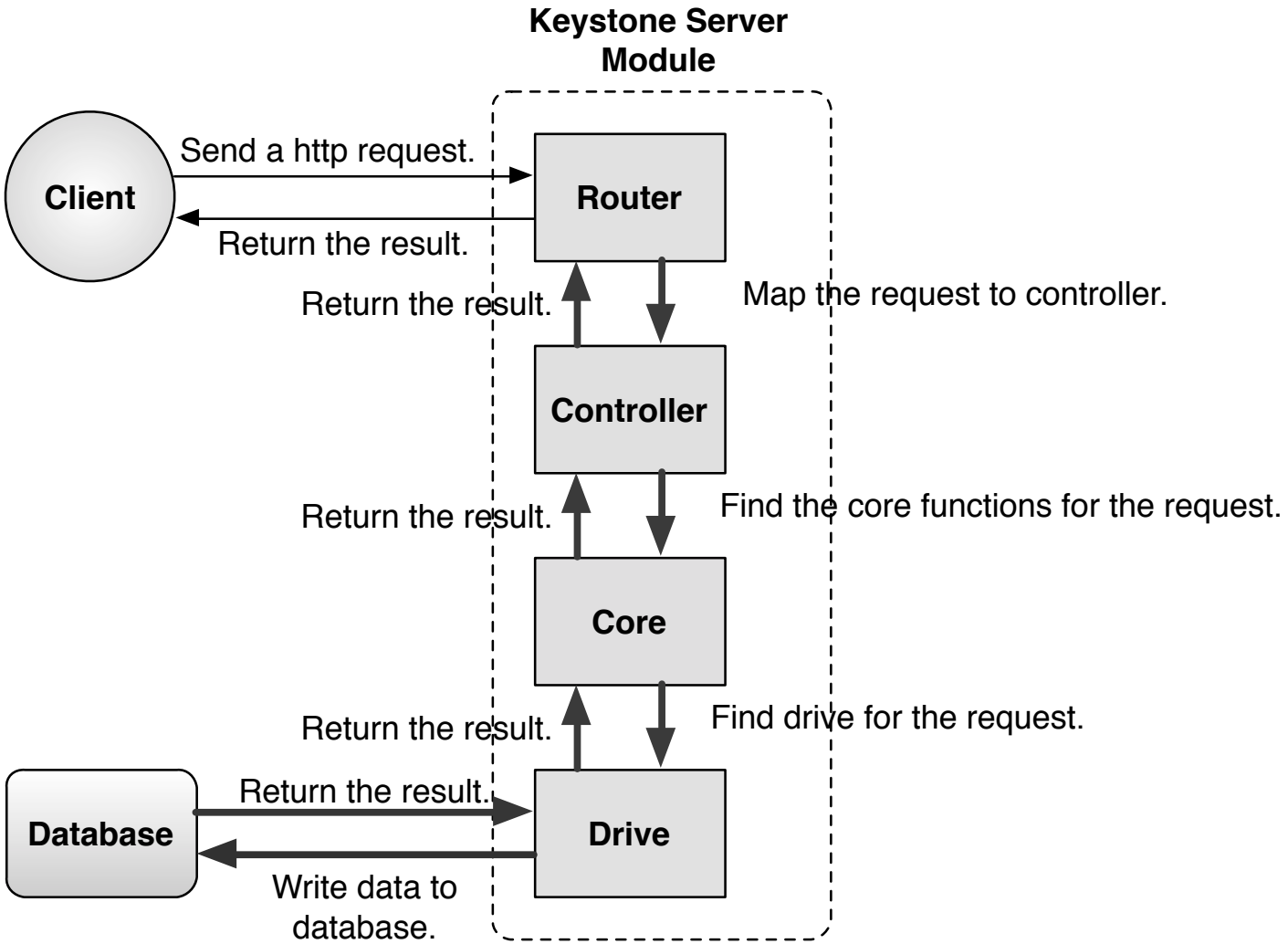
OSAC-SID Model



Enforcement - Keystone Protocol



Enforcement - Sid Request



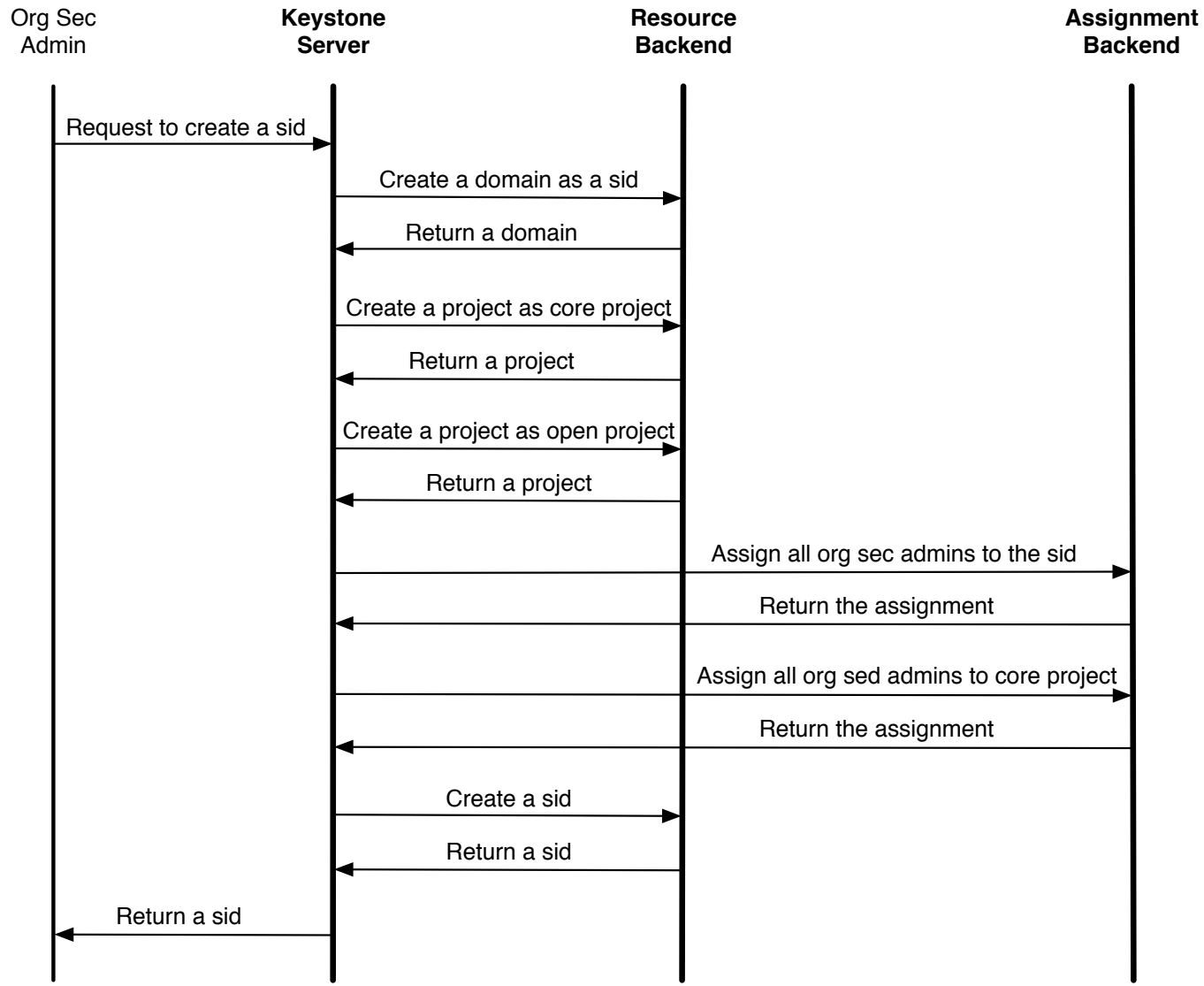
Enforcement - Backend

Sid Table in Database:

```
mysql> describe sid;
+--------------+-------------+------+-----+---------+-------+
| Field        | Type        | Null | Key | Default | Extra |
+--------------+-------------+------+-----+---------+-------+
| sid_id       | varchar(64) | NO   | PRI |         |       |
| sid_name     | varchar(64) | YES  |     | NULL    |       |
| sid_members  | text        | YES  |     | NULL    |       |
| core_project | varchar(64) | YES  |     | NULL    |       |
| open_project | varchar(64) | YES  |     | NULL    |       |
| extra        | text        | YES  |     | NULL    |       |
+--------------+-------------+------+-----+---------+-------+
```

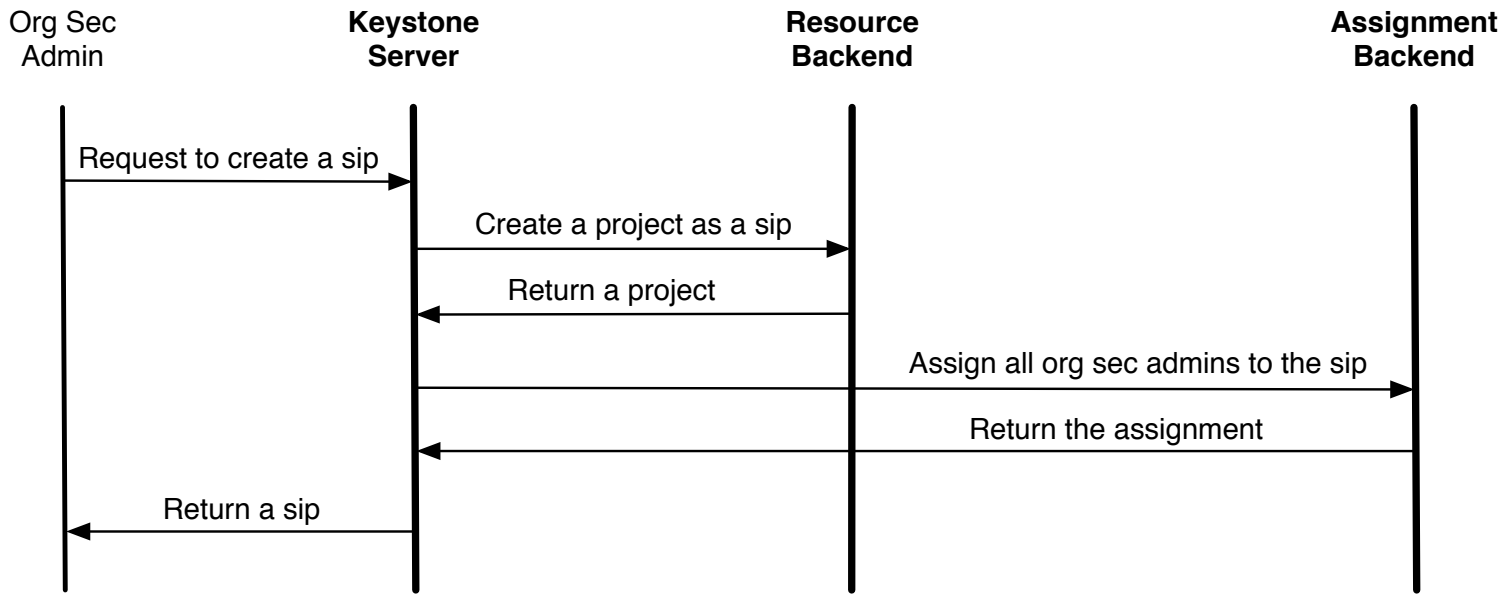
Enforcement

An Org SecAdmin Create a Sid:



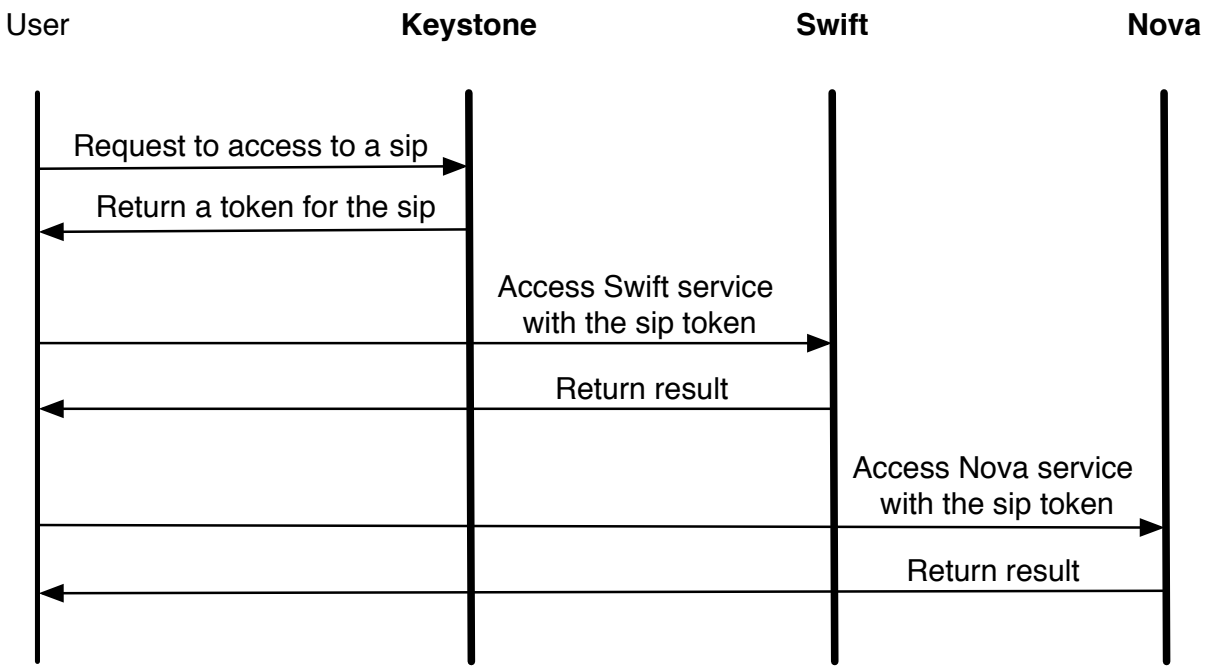
Enforcement

An Org SecAdmin Create a Sip:



Enforcement

A User Access to a Sip:



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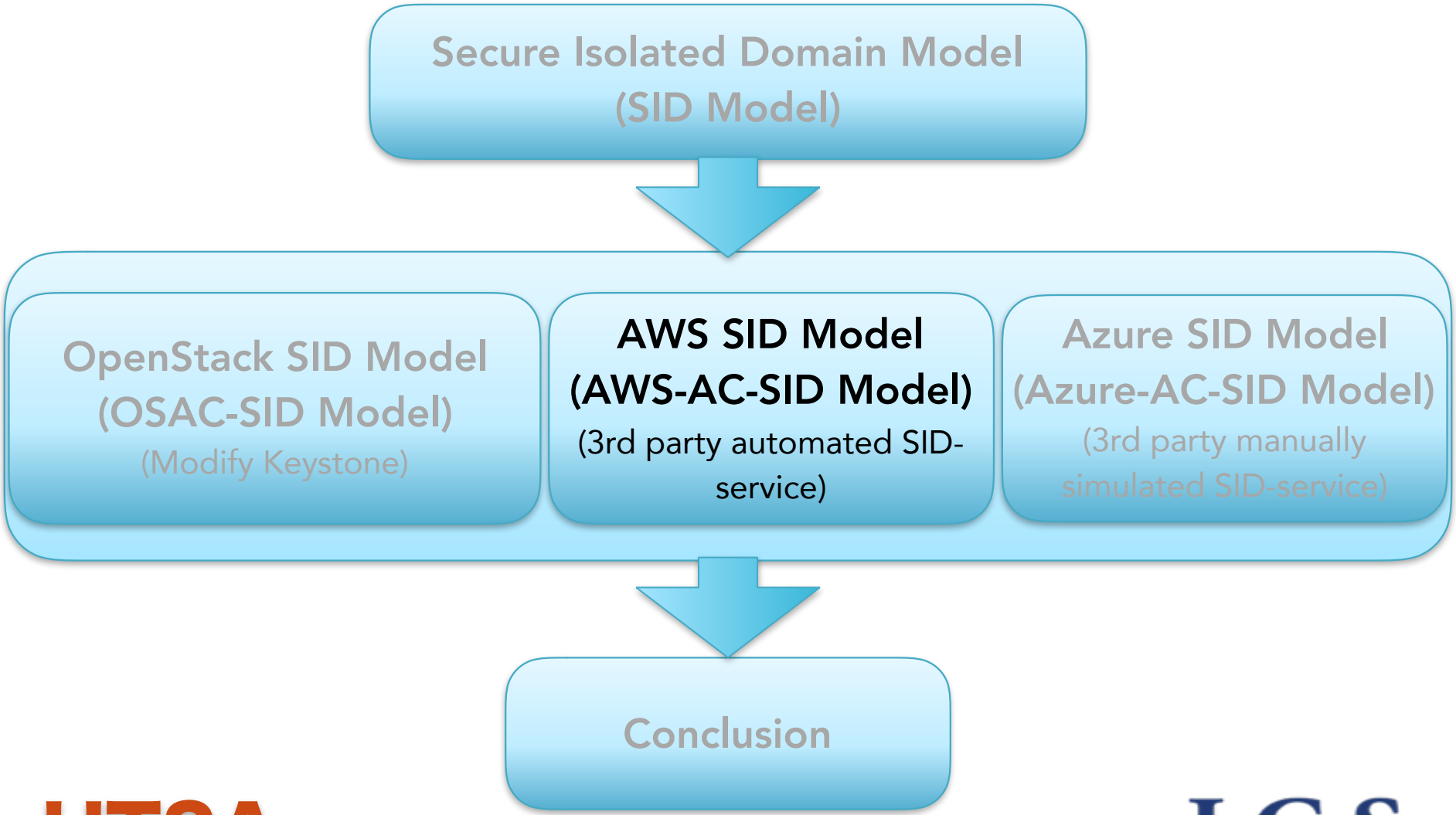
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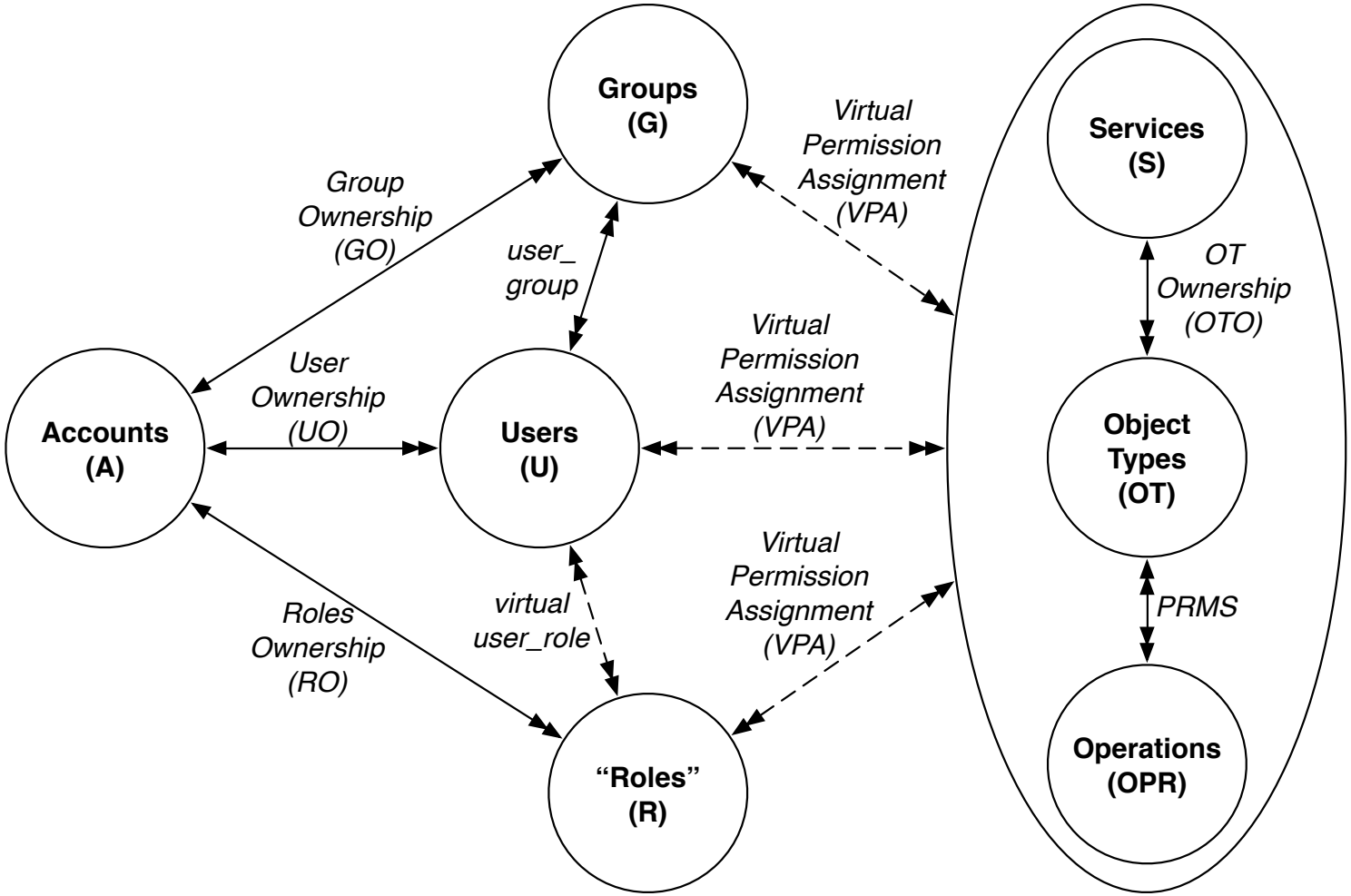
AWS Access Control (AWS-AC) Model

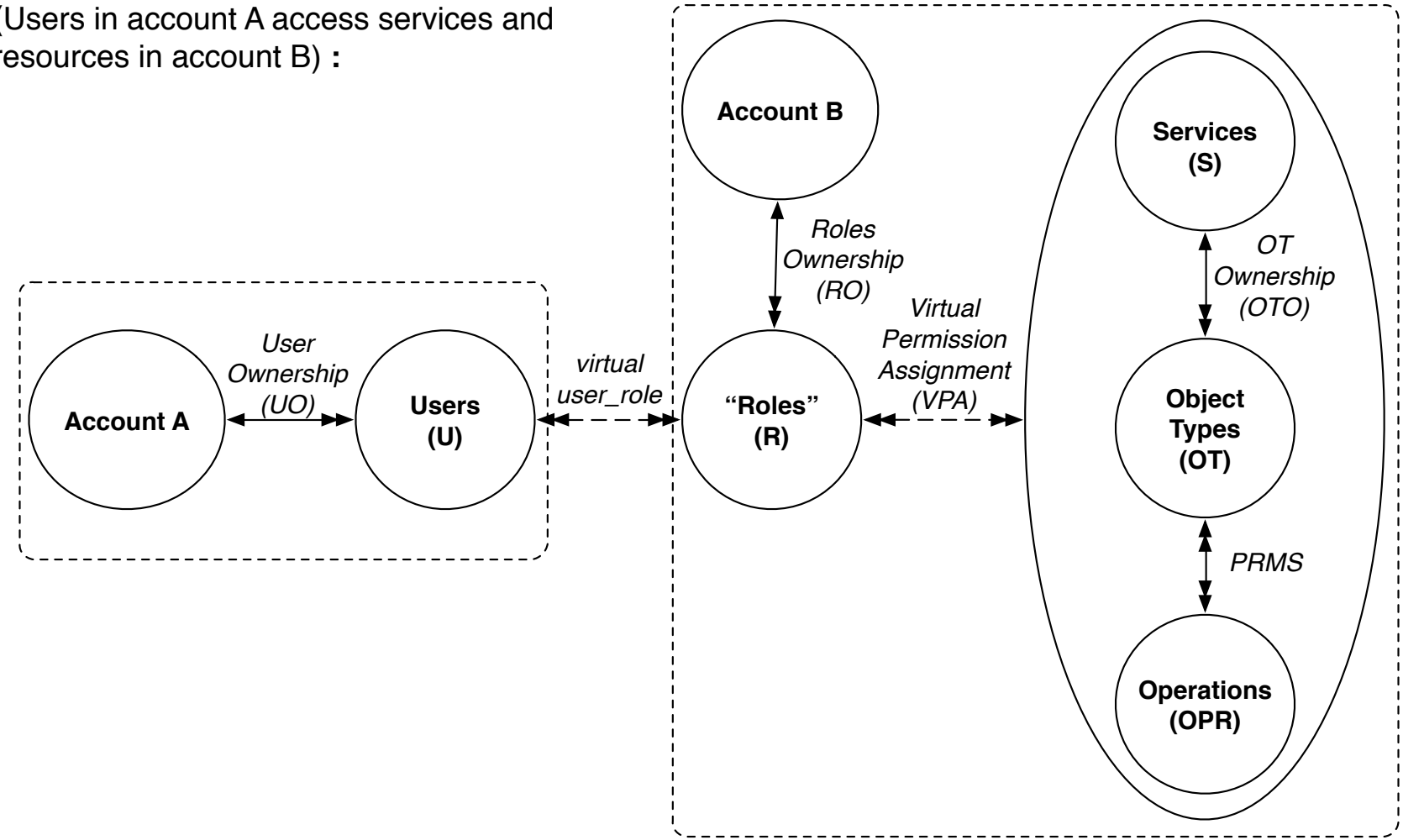
AWS Access Control within a Single Account:



Reference: Yun (Amy) Zhang, Farhan Patwa and Ravi Sandhu, Community-Based Secure Information and Resource Sharing in AWS Public Cloud. In Proceedings of the 1st IEEE International Conference on Collaboration and Internet Computing (CIC), 2015.

AWS Access Control (AWS-AC) Model

AWS Access Control across Accounts
(Users in account A access services and resources in account B) **:**



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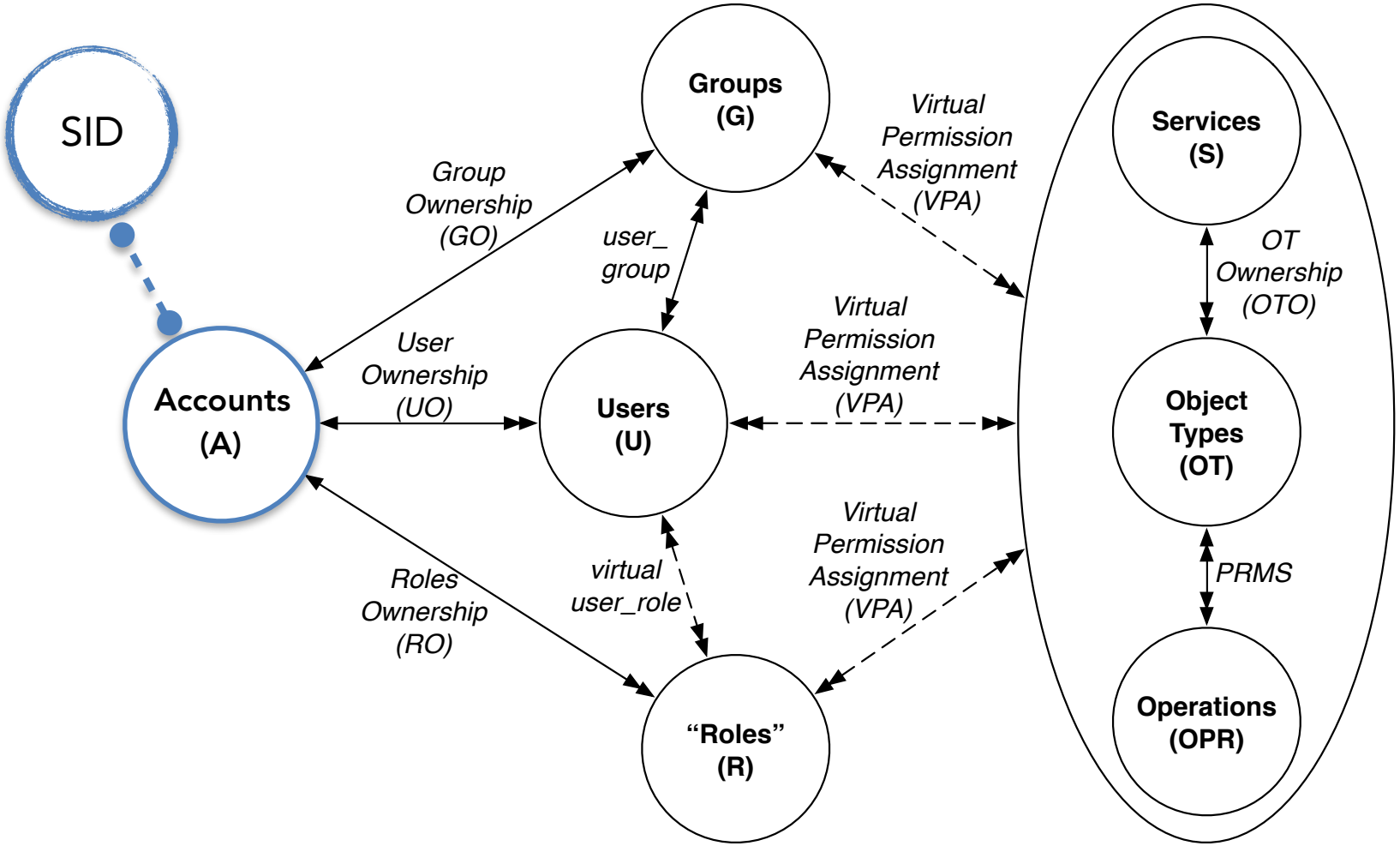
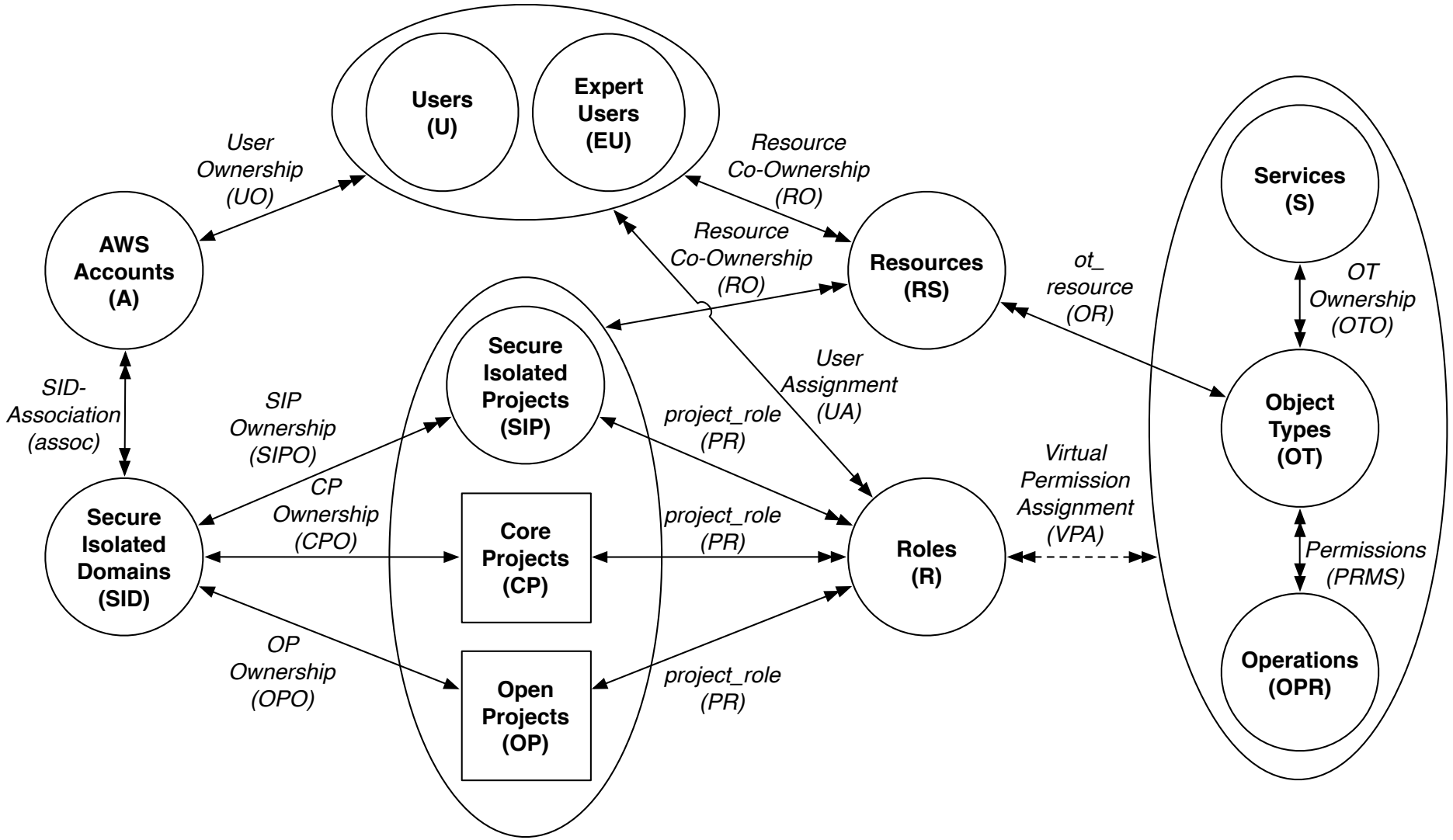
AWS-AC Model extends with SID

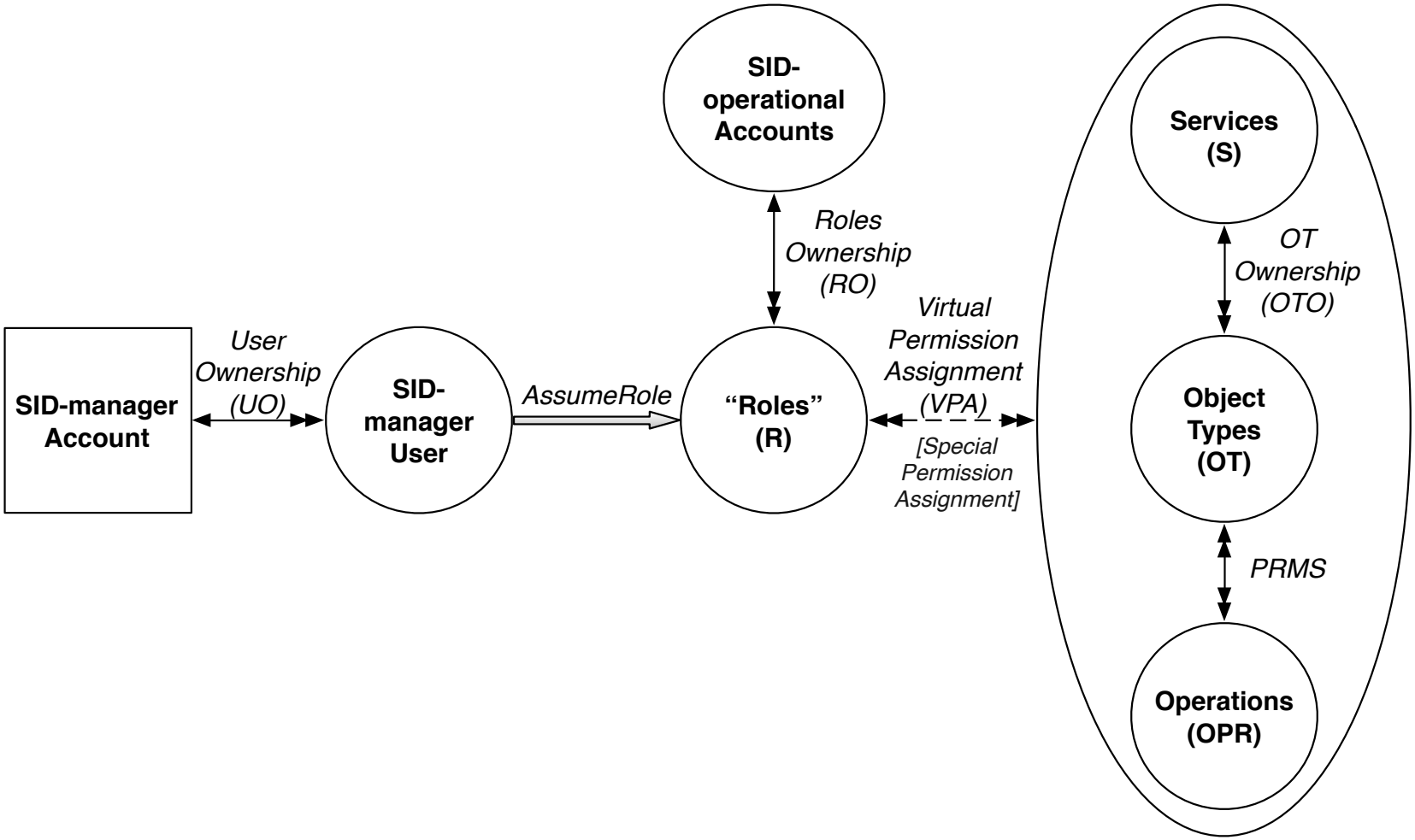
AWS Access Control within a Single Account:



AWS-AC-SID Model



Enforcement - Setup SID-service



Enforcement DataBase

sid_id	sid_name	sid_members	core_project	open_project
wbxiA97YH4c8jQARrGs1g7hkCjpHIKbu	Sid1	{"SAWS": "042298307144", "CPS": "934324332443"}	401991328752	434230153961

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SIDs Table in Database

sip_account_id	account_name	sip_members	status	sid_id
401991328752	Sid1_cp	{"SAWS": "042298307144", "CPS": "934324332443"}	1	j3molQAxgAn3jCayTFZLsi5IchTf9C1w
434230153961	Sid1_op	{"SAWS": "042298307144", "CPS": "934324332443"}	1	j3molQAxgAn3jCayTFZLsi5IchTf9C1w
557554226495	Sip1	{"SAWS": "042298307144", "CPS": "934324332443"}	1	j3molQAxgAn3jCayTFZLsi5IchTf9C1w
652714115935		{}	0	

4 rows in set (0.00 sec)

SIPs Table in Database

UTSA

I·C·S The Institute for Cyber Security

Enforcement - Policy

Core Project Admin User Policy:

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "AllowSecAdminToListRolesUsers",
            "Effect": "Allow",
            "Action": [
                "iam:ListRoles",
                "iam:ListUsers",
                "iam:ListPolicies",
                "iam:GetPolicy"
            ],
            "Resource": [
                "arn:aws:iam::*"
            ]
        }
    ]
}
```

Core Project Member User Policy:

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Action": "s3:*",
            "Resource": "*"
        },
        {
            "Effect": "Allow",
            "Action": "ec2:*",
            "Resource": "*"
        }
    ]
}
```

Enforcement - Across-account Access

User in org1 accesses resources in sid1:

AssumeRole in Org1:

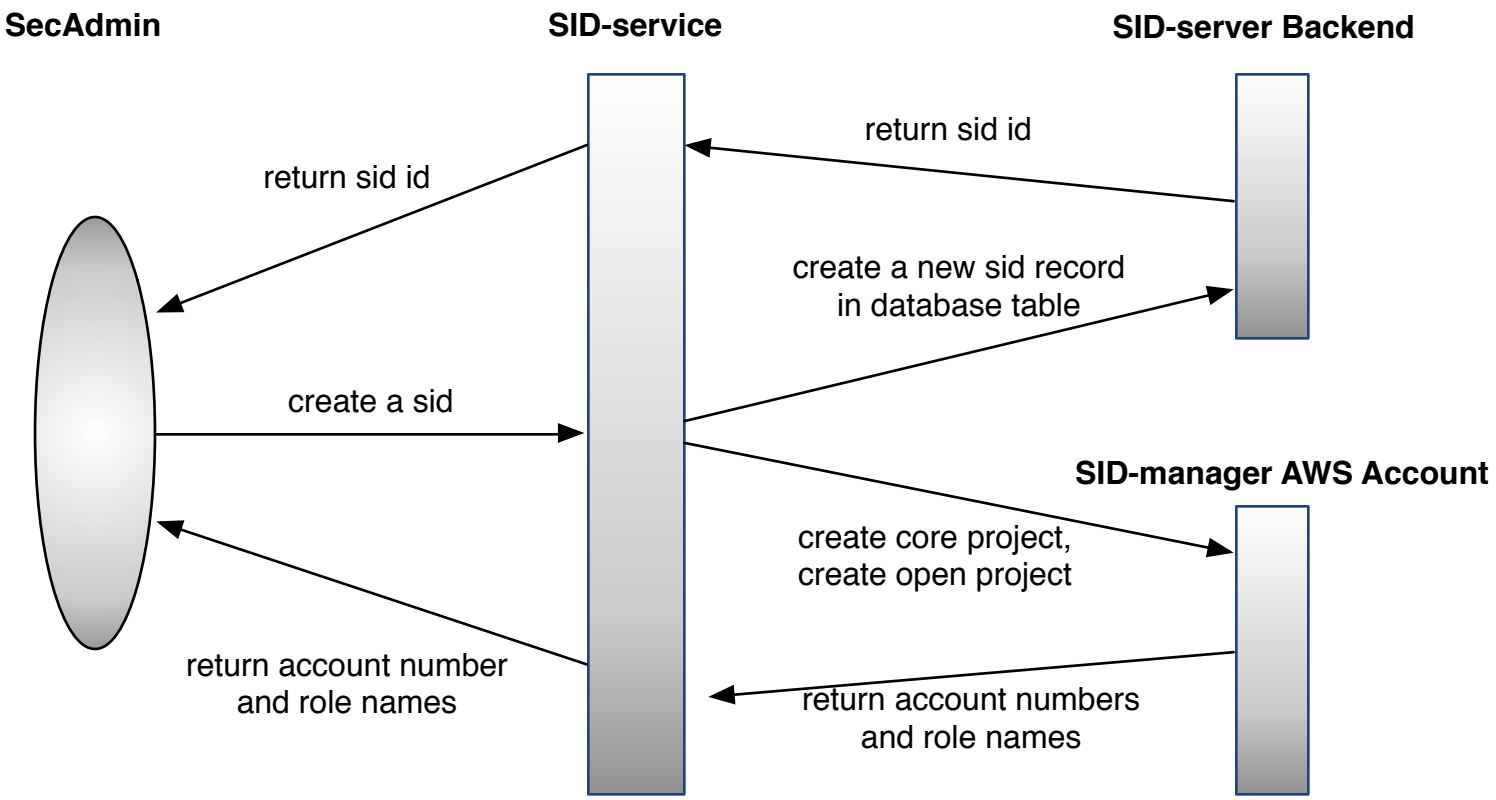
```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Action": "sts:AssumeRole",
            "Resource": "arn:aws:iam::*:*"
        }
    ]
}
```

Trust relationship in a Role in sid1:

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Sid": "",
      "Effect": "Allow",
      "Principal": {
        "AWS": "arn:aws:iam::123412341234:user/SipAdmin"
      },
      "Action": "sts:AssumeRole"
    }
  ]
}
```

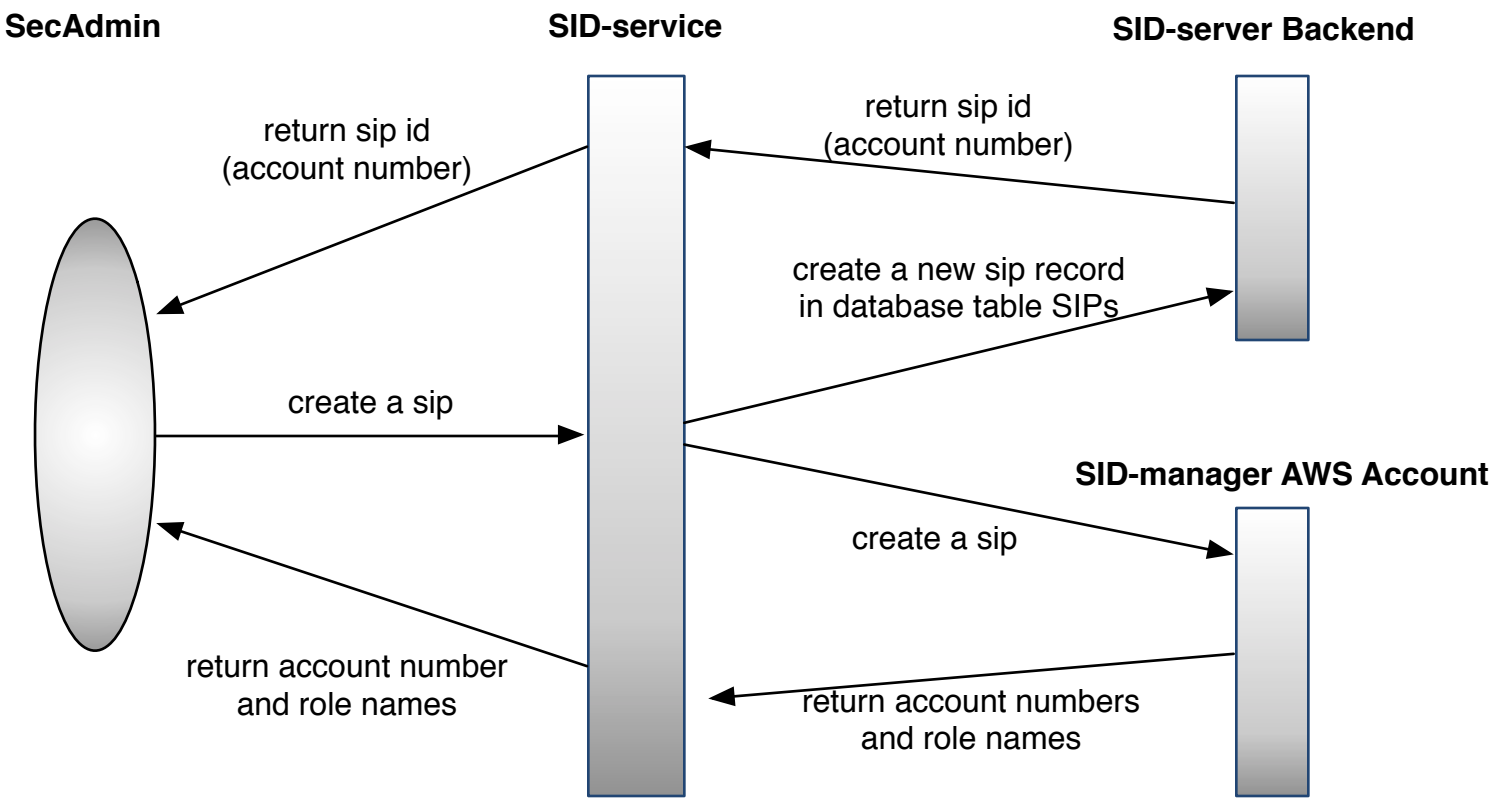
Enforcement

Process of Creating a Sid:

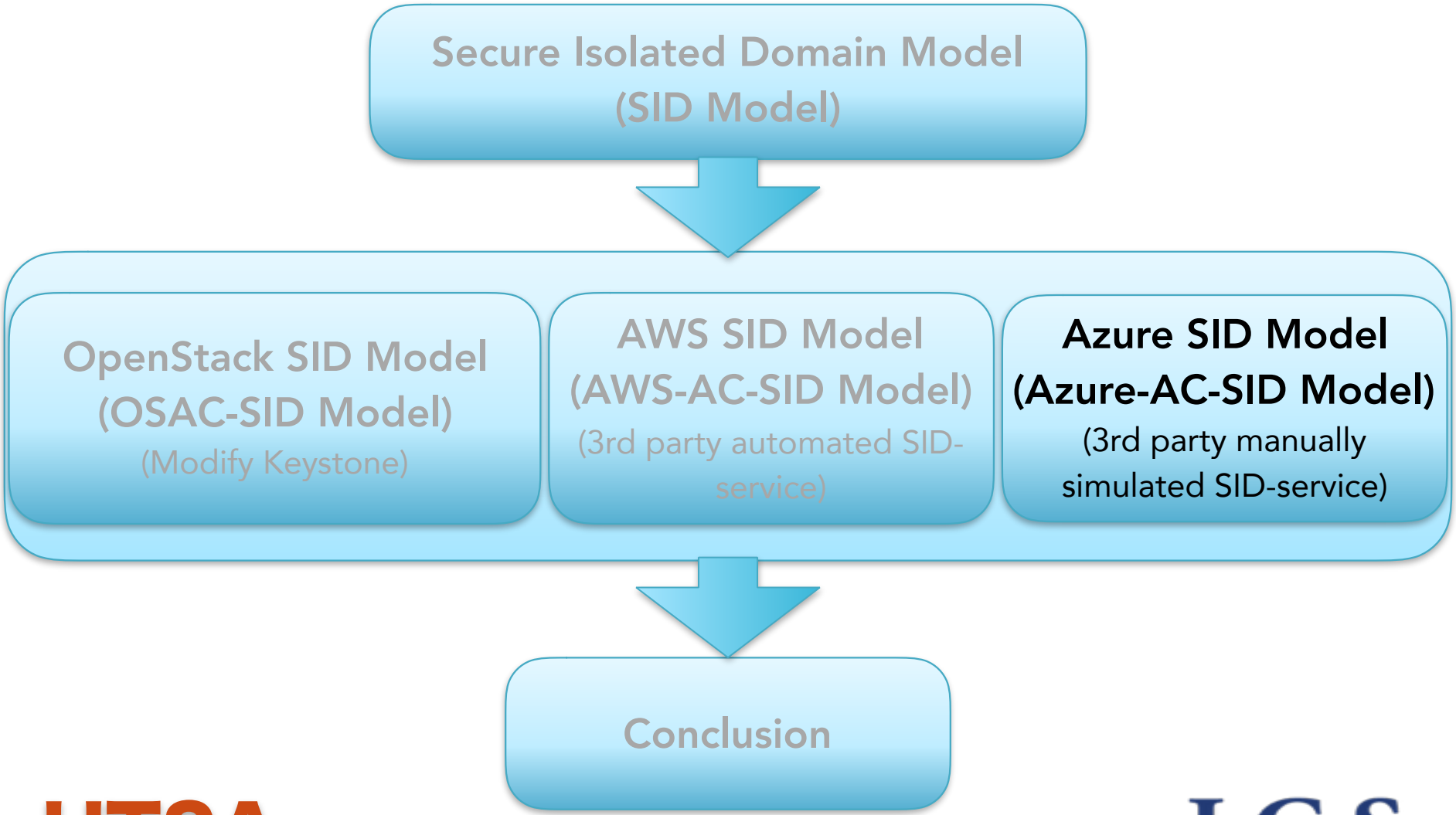


Enforcement

Process of Creating a Sip:

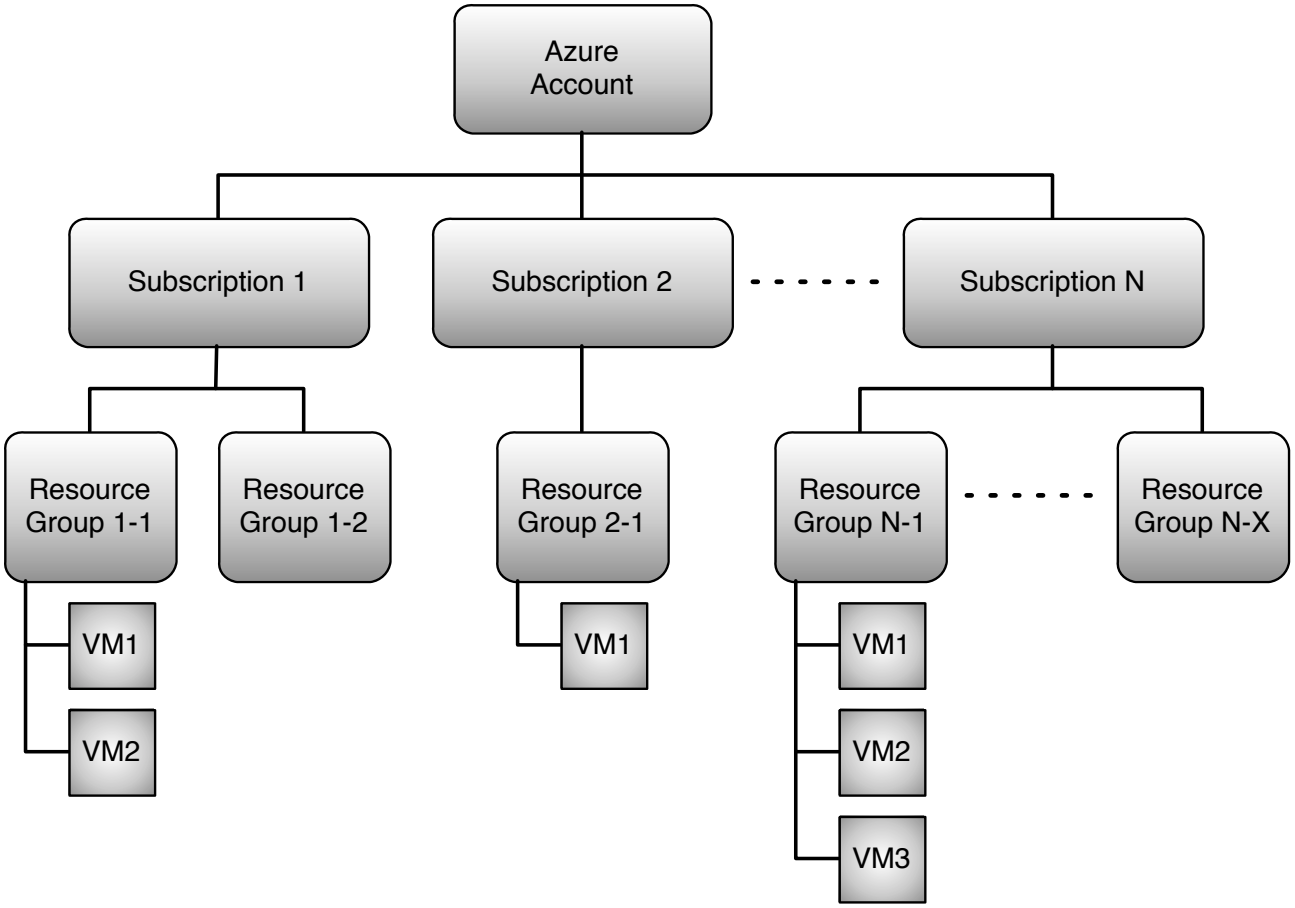


Outline

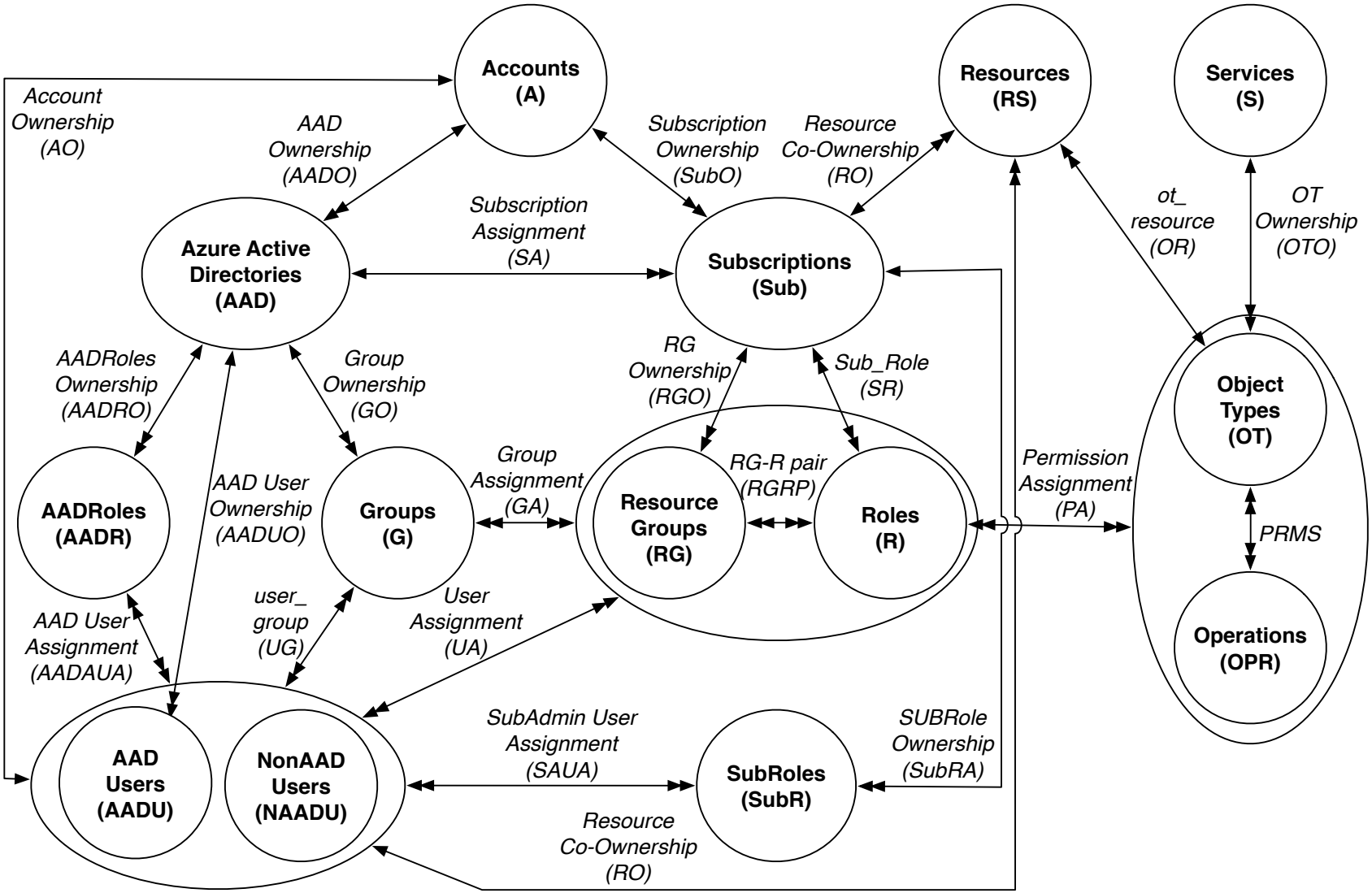

Secure Isolated Domain Model
(SID Model)
OpenStack SID Model
(OSAC-SID Model)
(Modify Keystone)
AWS SID Model
(AWS-AC-SID Model)
(3rd party automated SID-service)
Azure SID Model
(Azure-AC-SID Model)
(3rd party manually simulated SID-service)
Conclusion

Azure Introduction

- Azure Account Resource Division:

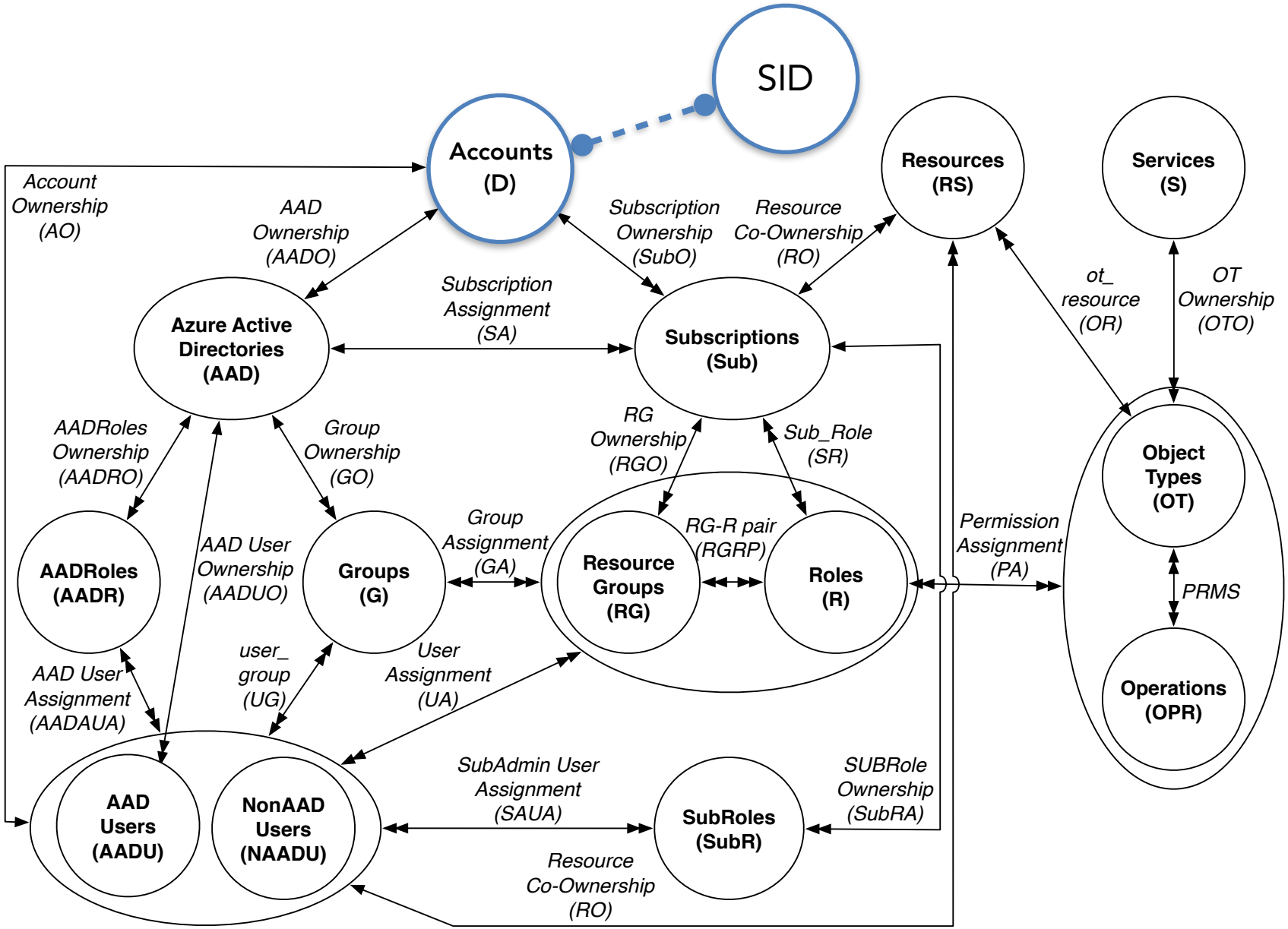


Azure Access Control (Azure-AC) Model

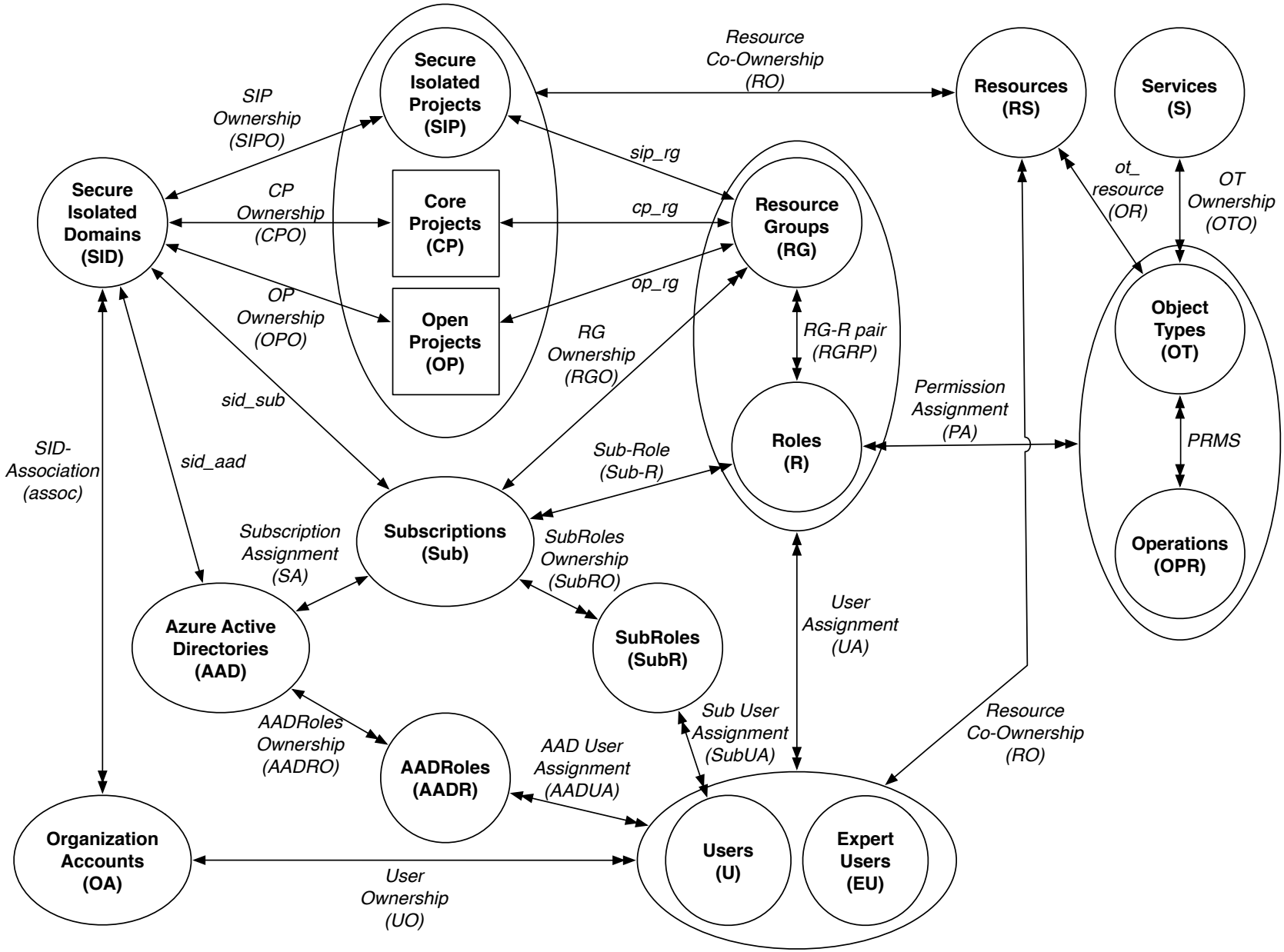


Reference: Yun (Amy) Zhang, Farhan Patwa and Ravi Sandhu, Community-Based Secure Information and Resource Sharing in Azure Cloud IaaS. In Proceedings of the 4th ACM Workshop on Security in Cloud Computing (SCC), 2016.

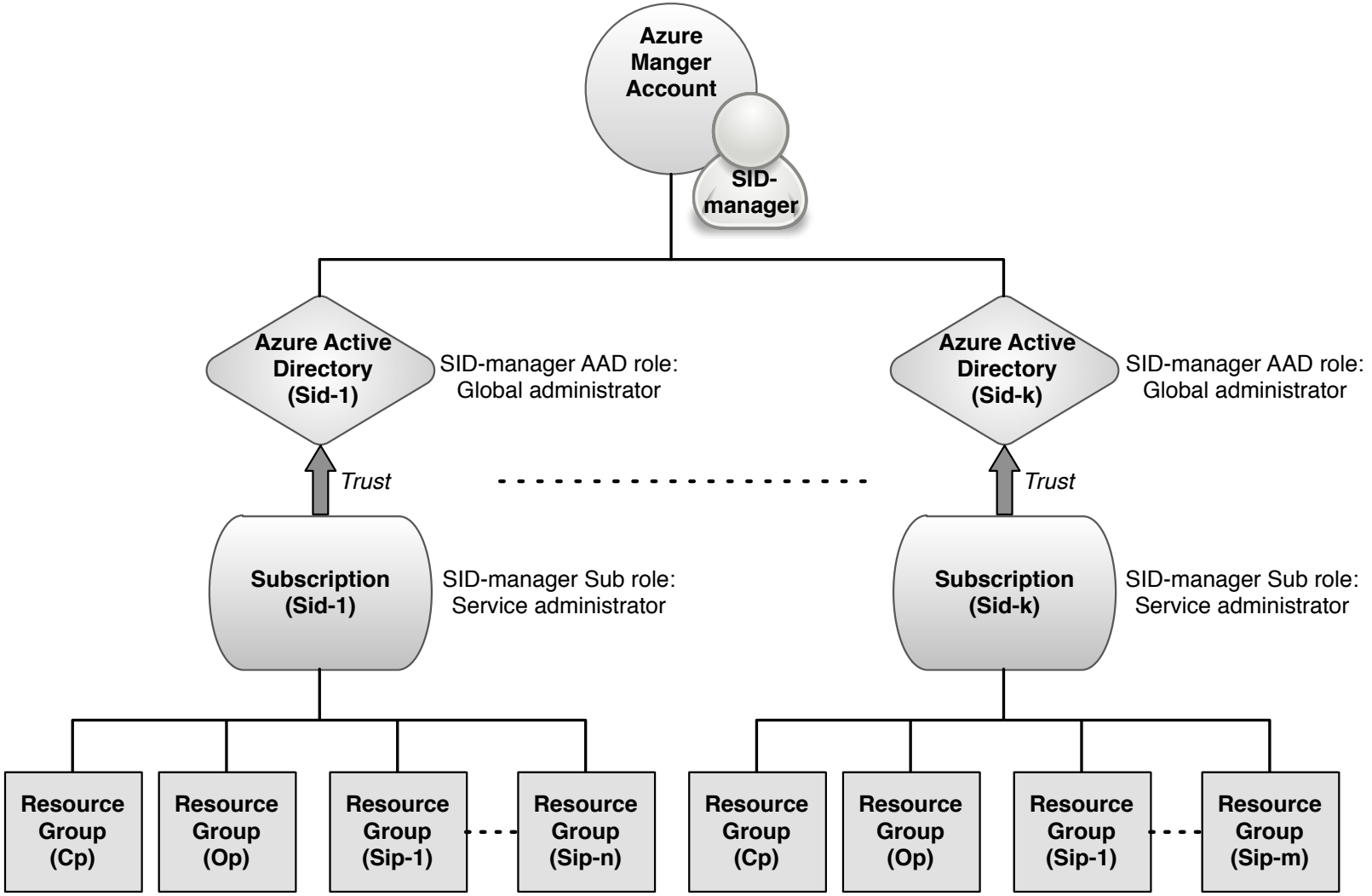
Azure-AC Model extends with SID



Azure-AC-SID Model

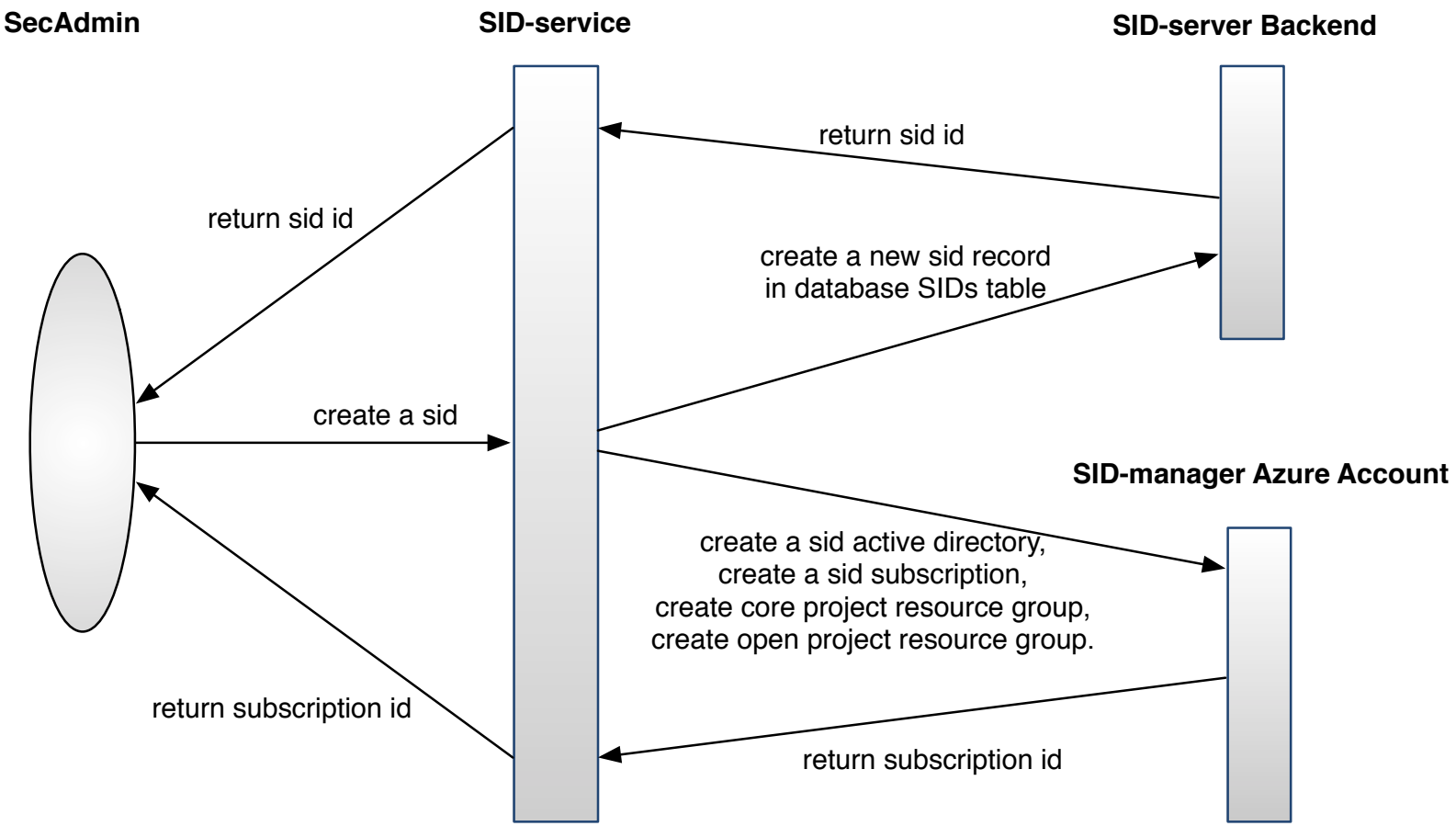


Enforcement



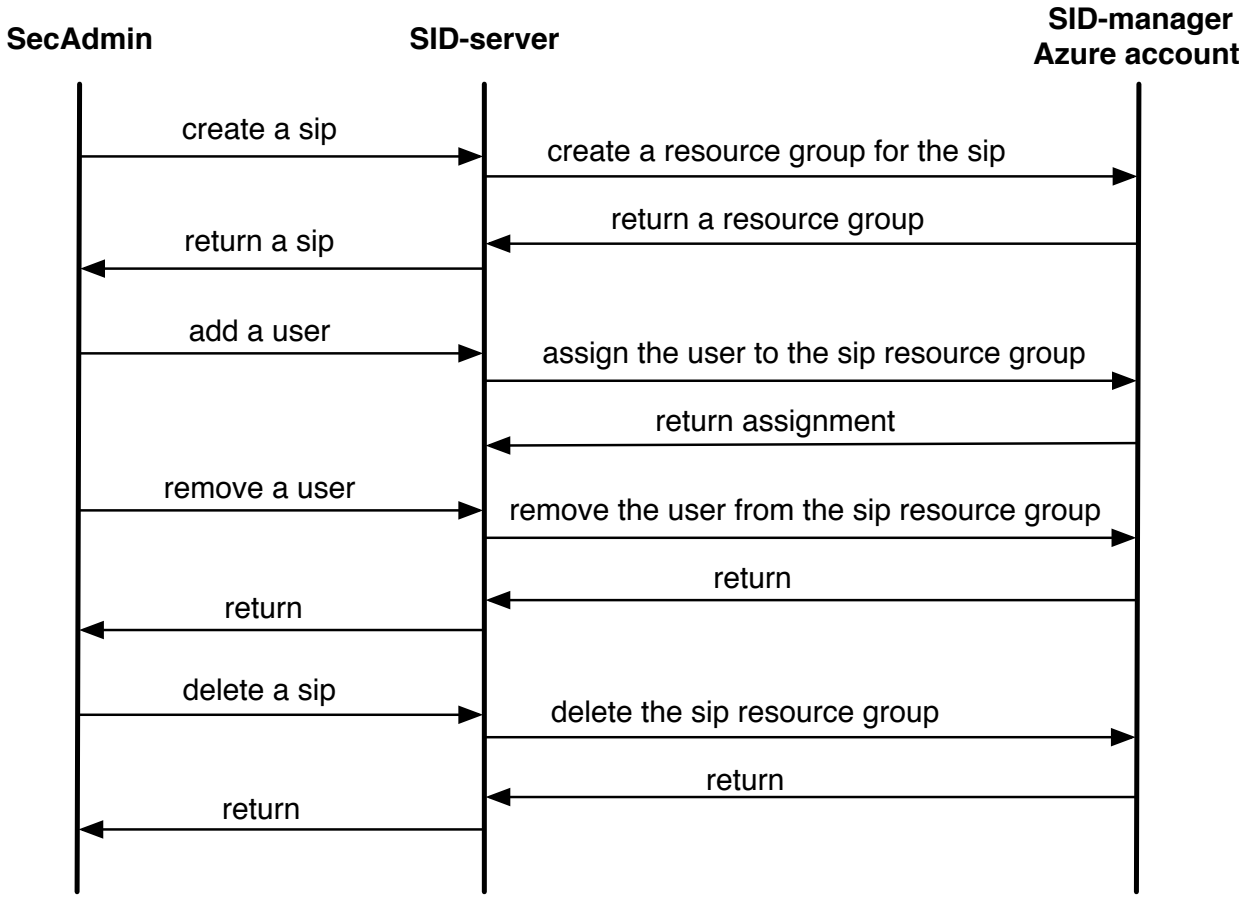
Enforcement

- Create a Sid:

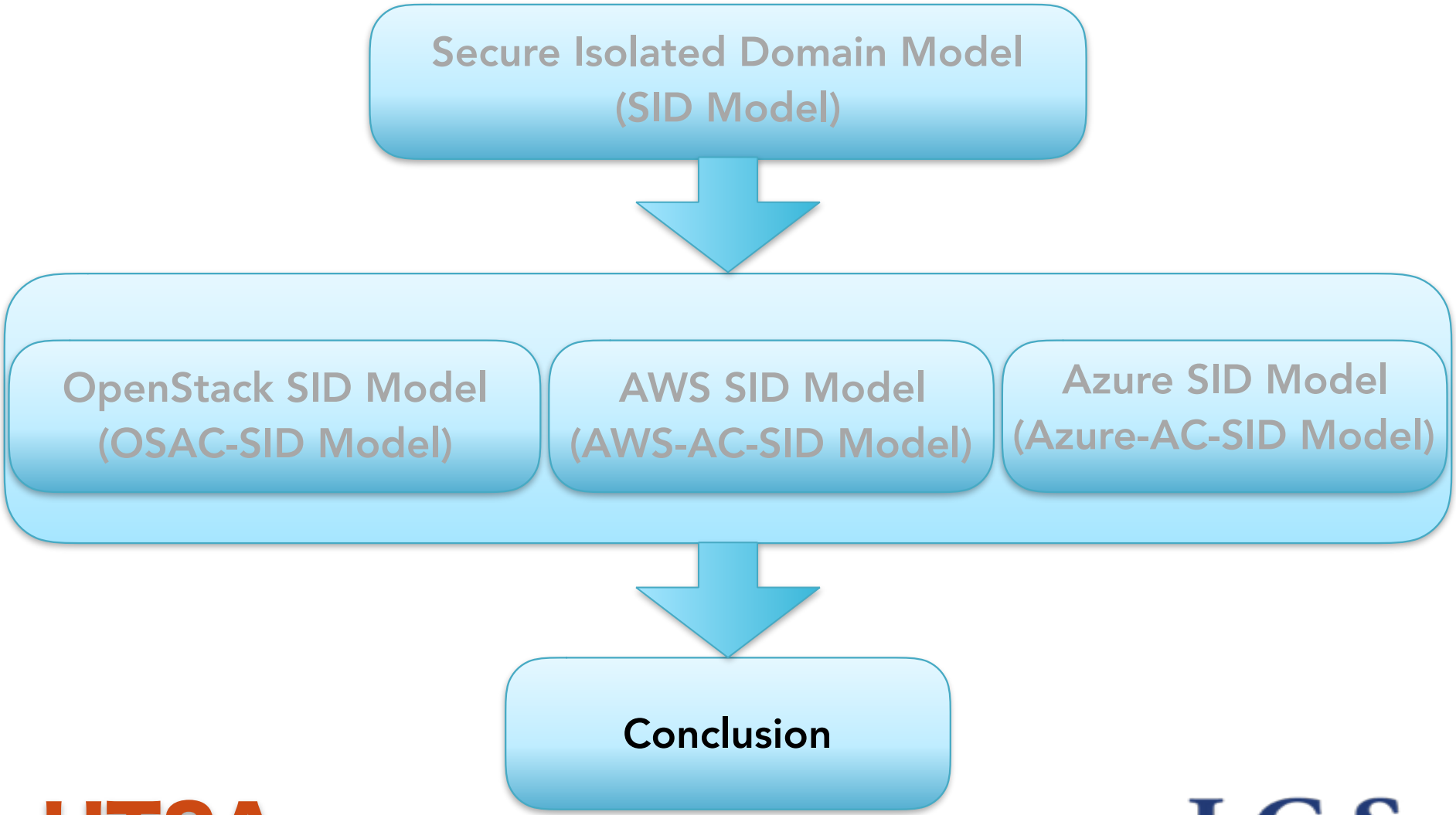


Enforcement

- SIP-requests:

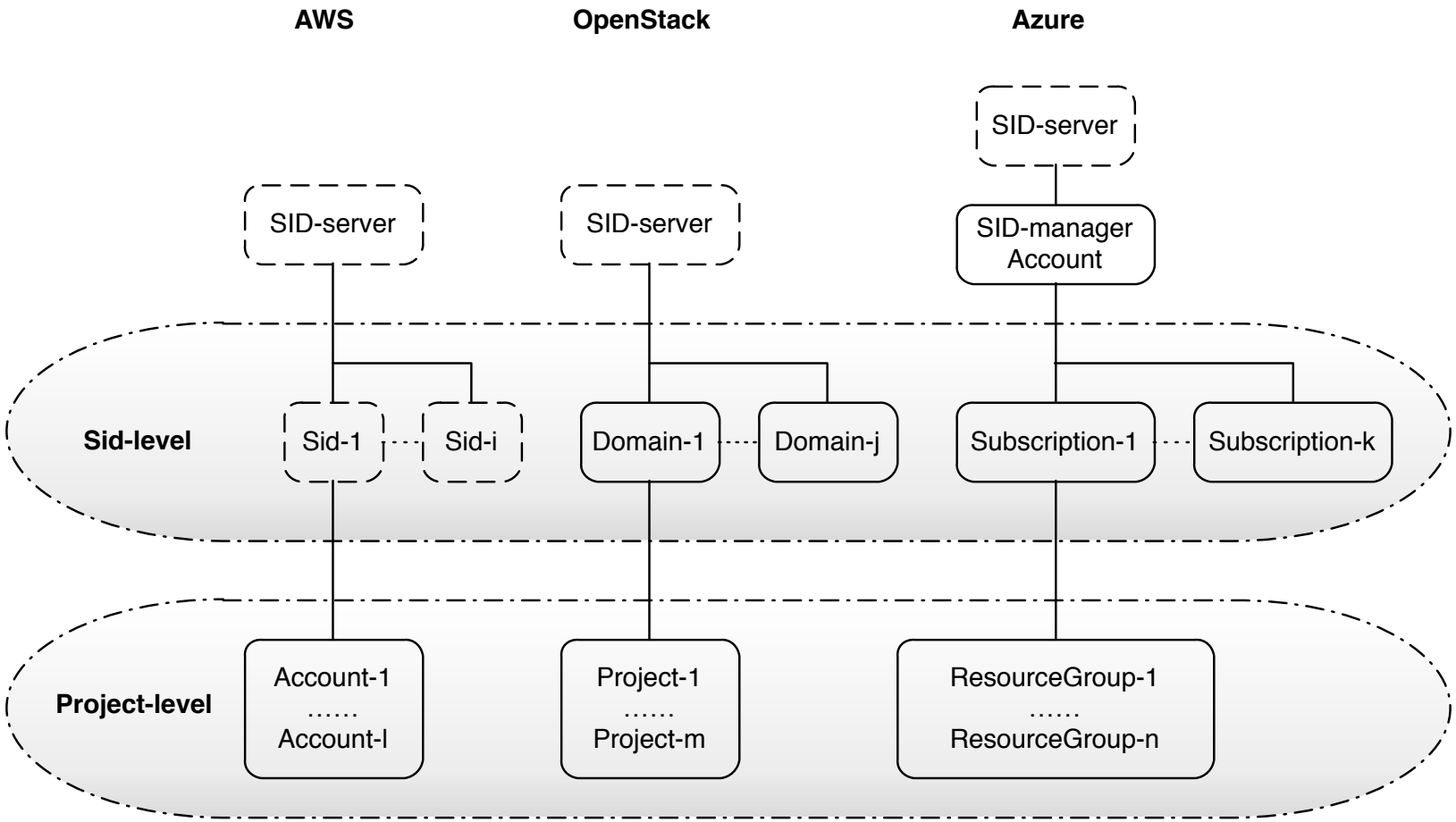


Outline


Secure Isolated Domain Model
(SID Model)
OpenStack SID Model
(OSAC-SID Model)
AWS SID Model
(AWS-AC-SID Model)
Azure SID Model
(Azure-AC-SID Model)
Conclusion

Model Comparison

- Resource Containers:



Model Comparison

- SID-services:
  - OpenStack
    - Modify cloud system itself
  - AWS & Azure
    - Build a third party SID-service server
- Roles:
  - OpenStack
    - Global roles
  - AWS
    - Local roles, with trust relations
  - Azure
    - Pre-defined roles & customized roles

Conclusion and future work

- Developed a sharing model (SID-model)
  - Formal specification
- Applied the model to three dominant IaaS cloud platforms (OpenStack, AWS and Azure)
  - Defined access control models for each cloud system
  - Extend it with SID
  - Enforcement
- Compare SID-model in different cloud system
- Future work suggestions
  - Try more control on a group of organizations creating a sid/sip;
  - Try more fine-grained roles inside a sid/sip;
  - Apply the model to multi-clouds.

Publications

- Yun (Amy) Zhang, Farhan Patwa and Ravi Sandhu, Community-Based Secure Information and Resource Sharing in Azure Cloud IaaS. *In Proceedings of the 4th ACM Workshop on Security in Cloud Computing (SCC)*, May 30, 2016, Xi'an, China, 8 pages.
- Yun (Amy) Zhang, Farhan Patwa and Ravi Sandhu, Community-Based Secure Information and Resource Sharing in AWS Public Cloud. *In Proceedings of the 1st IEEE International Conference on Collaboration and Internet Computing (CIC)*, Hangzhou, China, October 27-30, 2015, 8 pages.
- Yun (Amy) Zhang, Farhan Patwa, Ravi Sandhu and Bo Tang, Hierarchical Secure Information and Resource Sharing in OpenStack Community Cloud. *In Proceedings 16th IEEE Conference on Information Reuse and Integration (IRI)*, San Francisco, California, August 13-15, 2015, 8 pages.
- Yun (Amy) Zhang, Ram Krishnan and Ravi Sandhu, Secure Information and Resource Sharing in Cloud. *In Proceedings of the 5th ACM Conference on Data and Application Security and Privacy (CODASPY) Poster Session*, March 2-4, 2015, San Antonio, Texas, pages 131-133.
- Yun (Amy) Zhang, Ram Krishnan and Ravi Sandhu, Secure Information and Resource Sharing in Cloud Infrastructure as a Service. *In Proceedings of ACM Workshop on Information Sharing and Collaborative Security (WISCS 2014),* November 3, 2014, Scottsdale, AZ.


Thanks!