Dynamic Groups and Attribute-Based Access Control for Next-Generation Smart Cars

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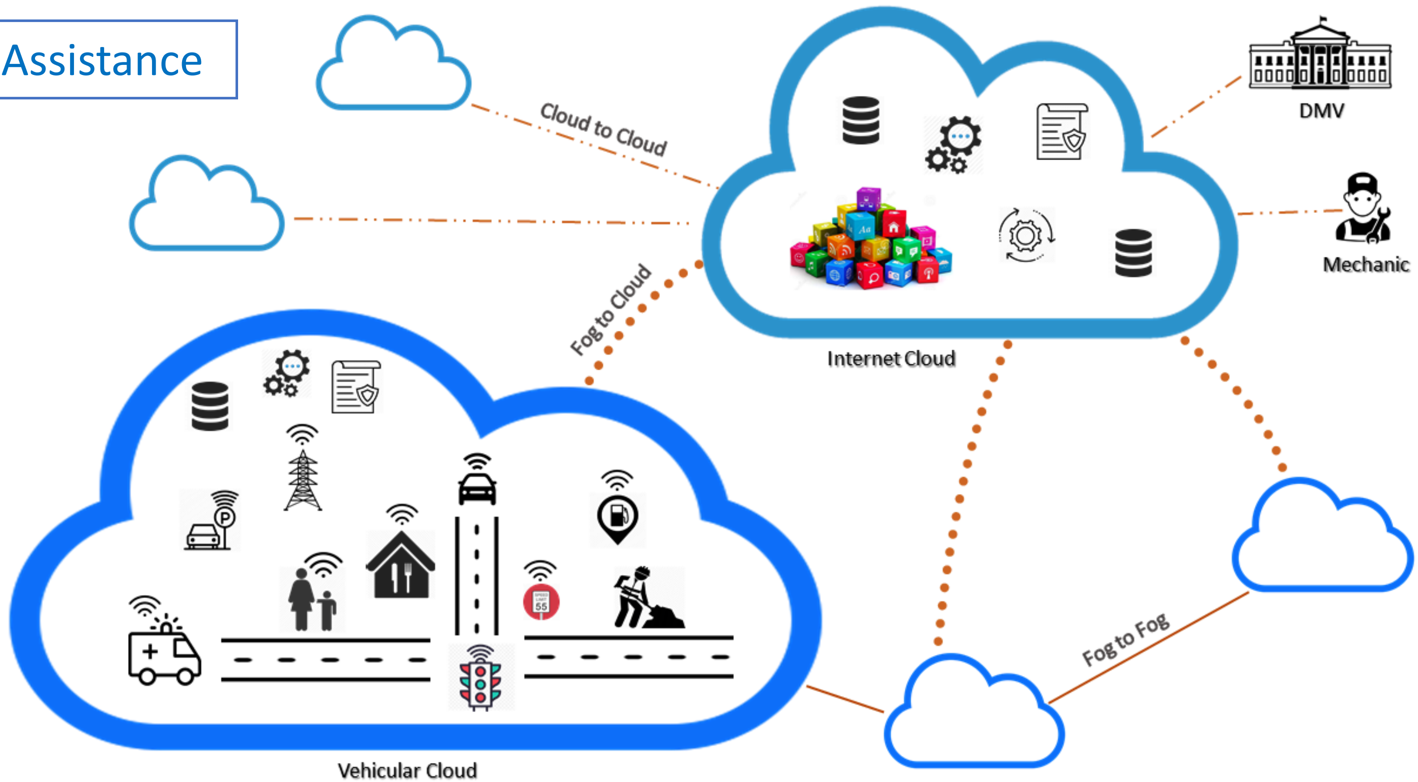
Smart Cars Ecosystem

Safety and Assistance

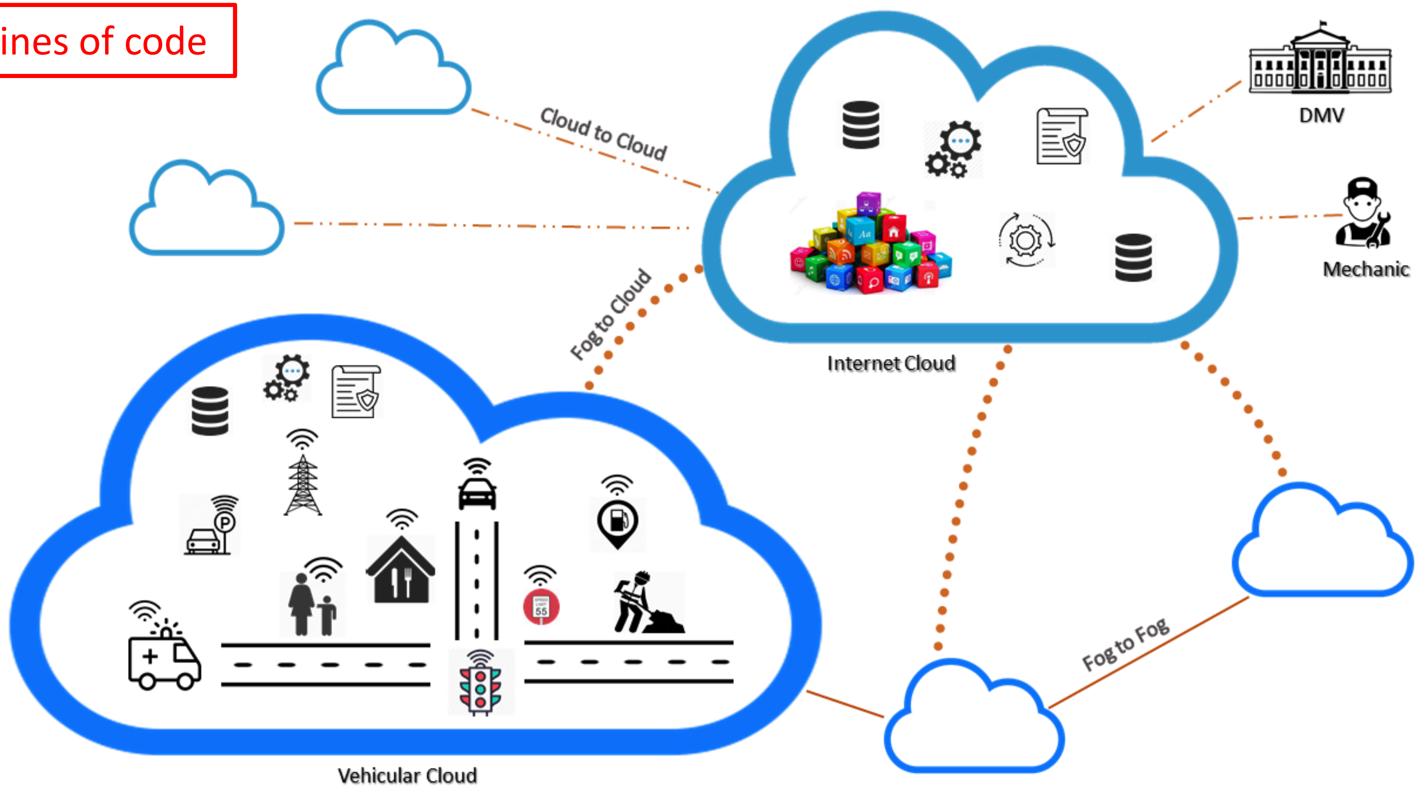


Information and Entertainment

High Mobility, Location Centric
Time Sensitive, Dynamic Pairing
Multiple Fog/Cloud Infrastructures

No More Isolated.!

100 million lines of code



Software Reliance , Broad Attack Surface, Untrusted Entities

Attribute Based Access Control

- ABAC: Decision based on the attributes of entities
- Attributes are name value pair: age (Alice) → 29
- Core entities in ABAC include:
  - Users
  - Objects
  - Environment or Context
  - Operations

  } **Attributes**
- Authorization Policies: determine rights just in time
  - retrieve attributes of relevant entities in request
- Enhance flexibility and fine grained access control

Access Control Needs in Smart Cars

- On-Board Data, Applications and Sensors
- User Privacy Preferences
- Over the Air updates
- V2X fake messages
- Third Party devices
- Loss of Information in Cloud
- Location and time sensitivity of the services.
- In-vehicle communication

Scope of Contribution

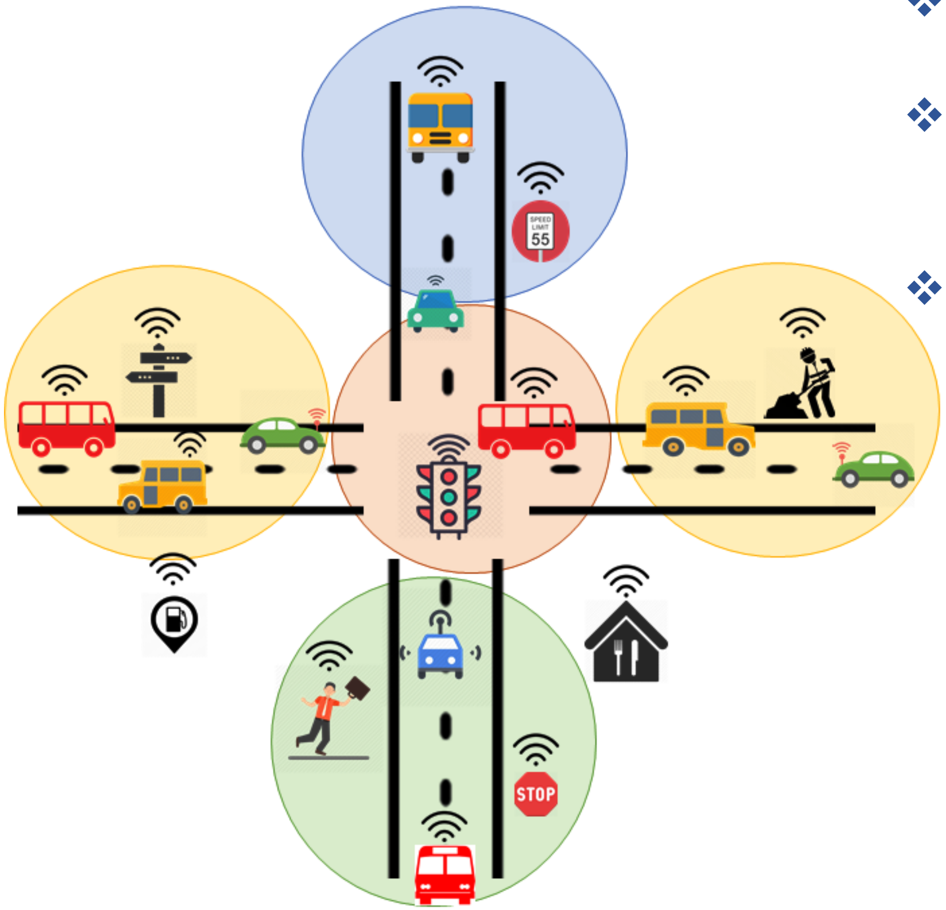
Contribution

- Propose formalized ABAC model for cloud assisted applications.
- Dynamic groups and user preferences.
- Implementation of the model in AWS.

Scope

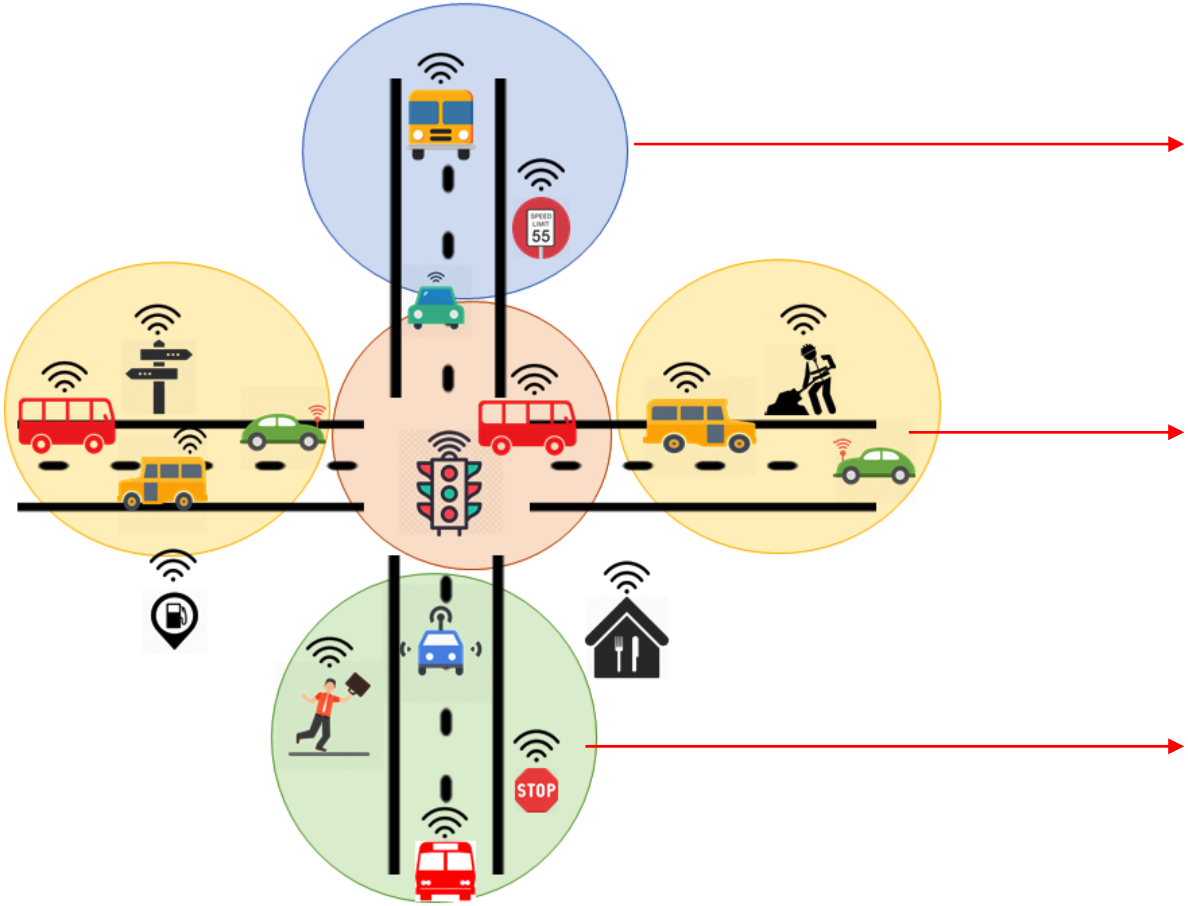
- Single Central Cloud
- No direct access and physical tampering
- Communication Channel is encrypted.
- Data in Cloud is secure
- In-vehicle security not considered

Location Groups



- Categorizing wide locations into smaller groups.
- Vehicles dynamically become member based on current GPS, vehicle-type or individual user preferences.
- Ensure relevance of alerts and notifications

Attributes and Alerts



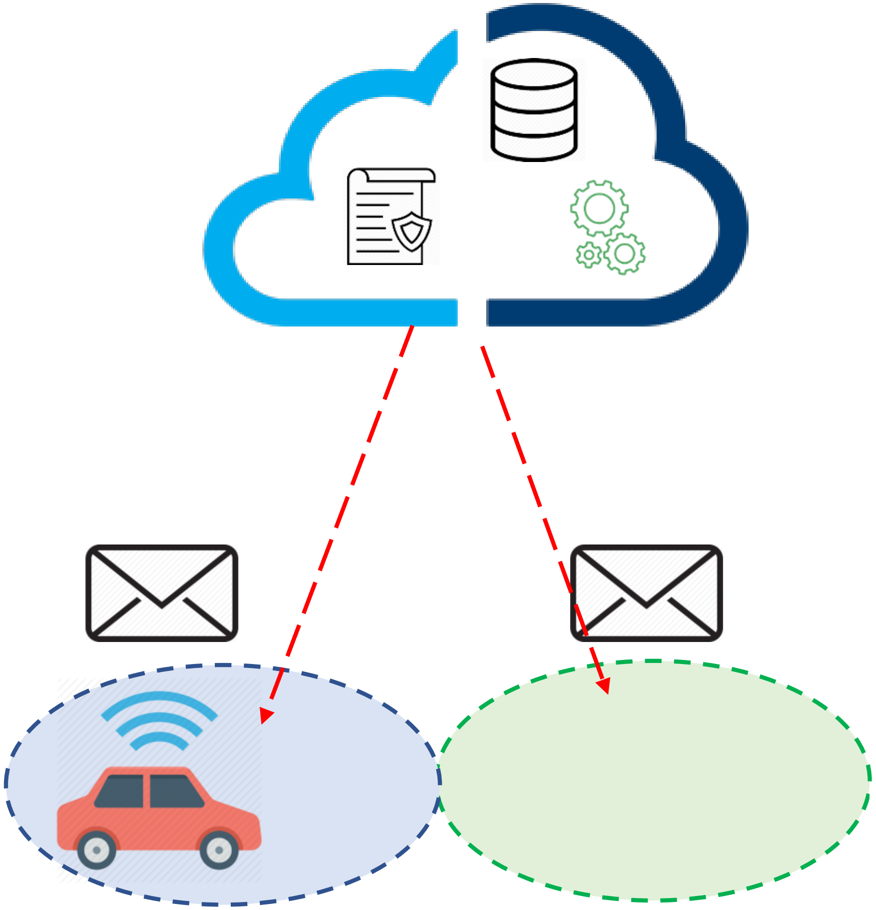
Speed Limit: 50 mph
Deer Threat: ON
Ice on Road: NO

Speed Limit: 30 mph
Flood Warning: ON
Road Work: ON

Speed Limit: 20 mph
School Zone: ON
Amber Alert: ABC123

Vehicle moves and are assigned to different groups and inherits their attributes/alerts.

Using Location Groups



Speed Limit: 50 mph
Deer Threat: ON
Ice on Road: NO

Speed Limit: 30 mph
Flood Warning: ON
Road Work: ON

Administrative Questions:

- How the attributes or alerts of groups are updated?
- How are moving entities assigned to groups?
- How groups hierarchy is created?

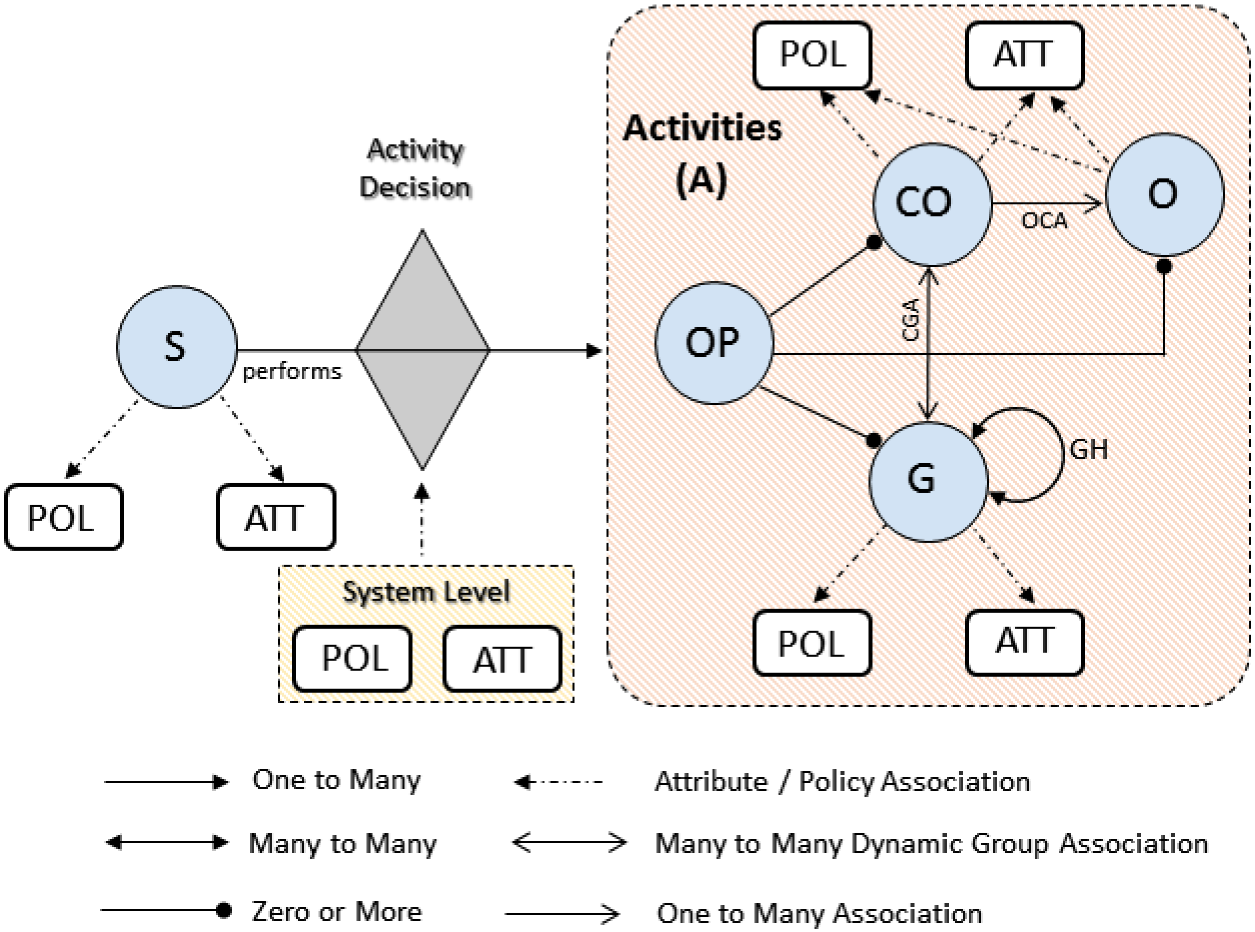
Operational Questions:

- How attributes and groups are used to provide security?
- How user privacy preferences are considered?

{"state": {"reported": {"Latitude": "29.4769353",
"Longitude":"-98.5018237"}}}

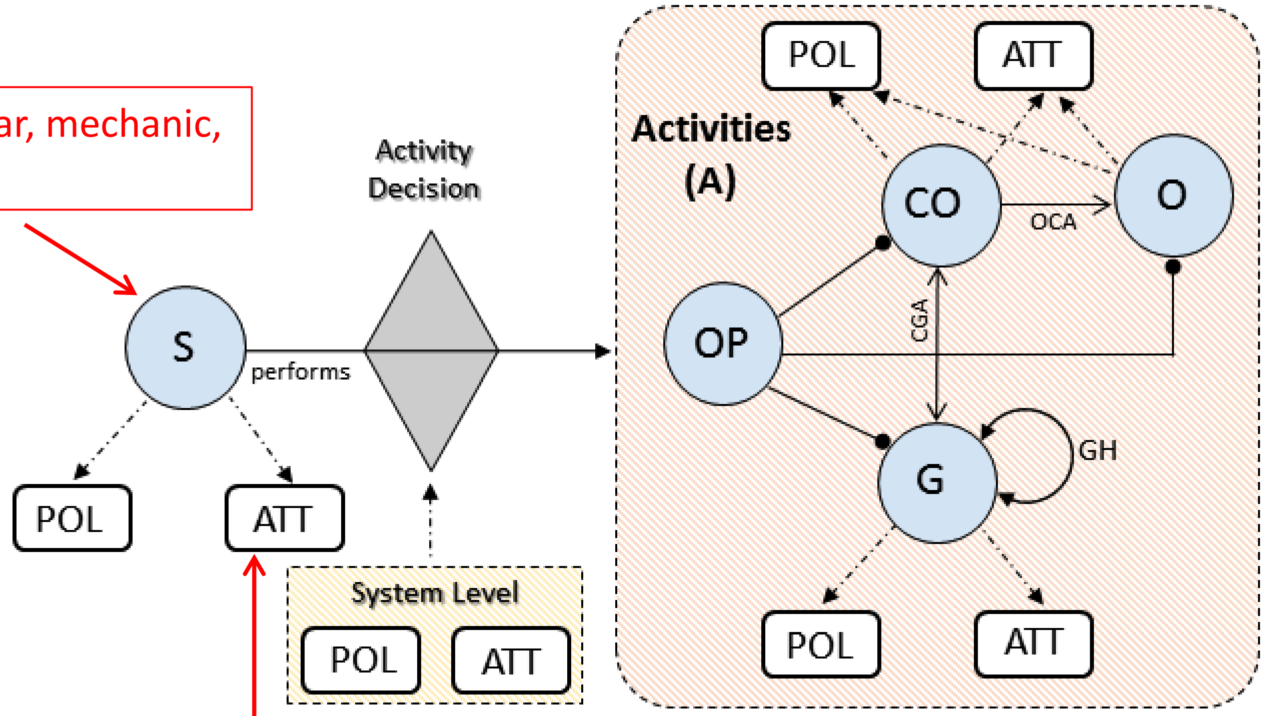
Reported MQTT message

CV-ABAC$_G$ Model



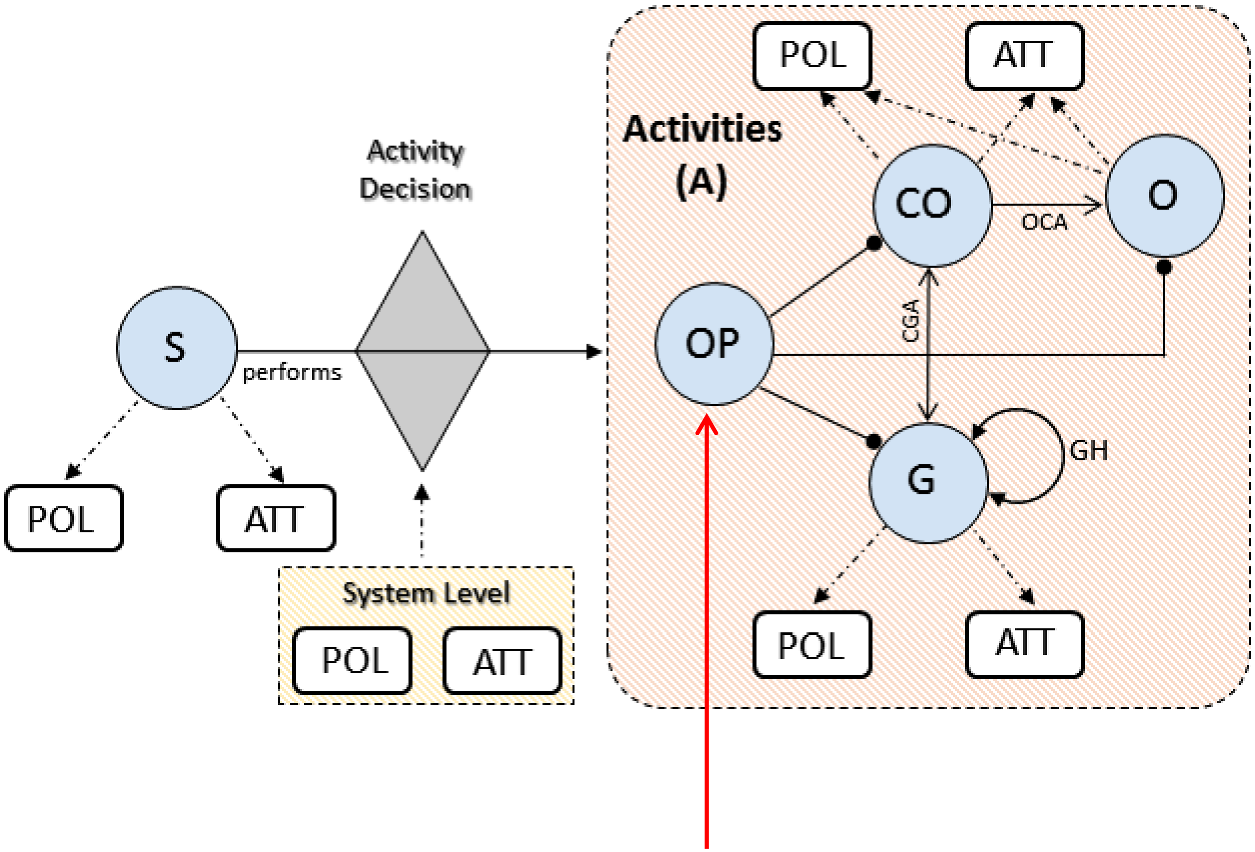
Model Components

user, sensor, car, mechanic, restaurant



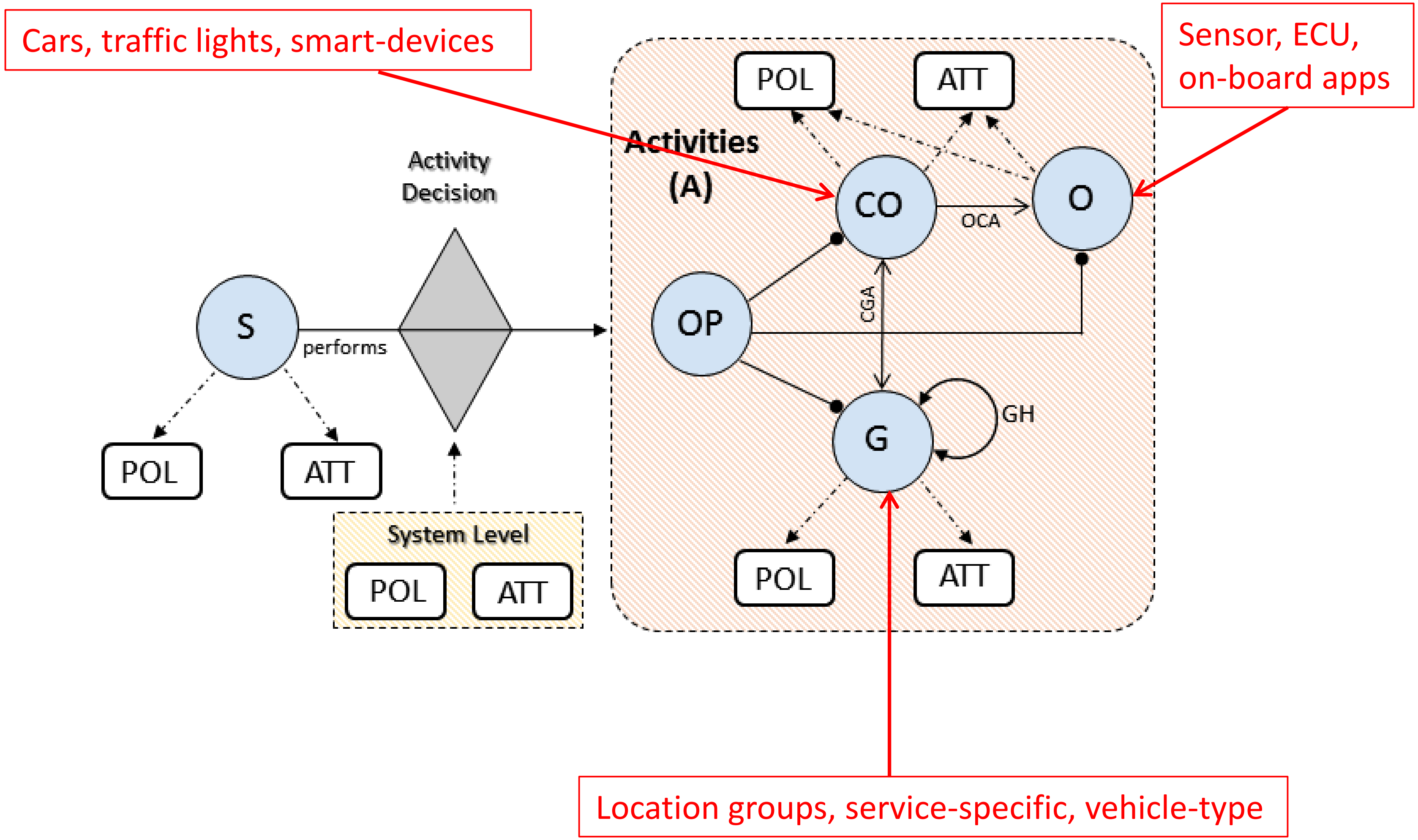
{ location, size, IP, direction, speed, VIN, cuisine-type}

Model Components



{ read, write, control, notify, administrative actions }

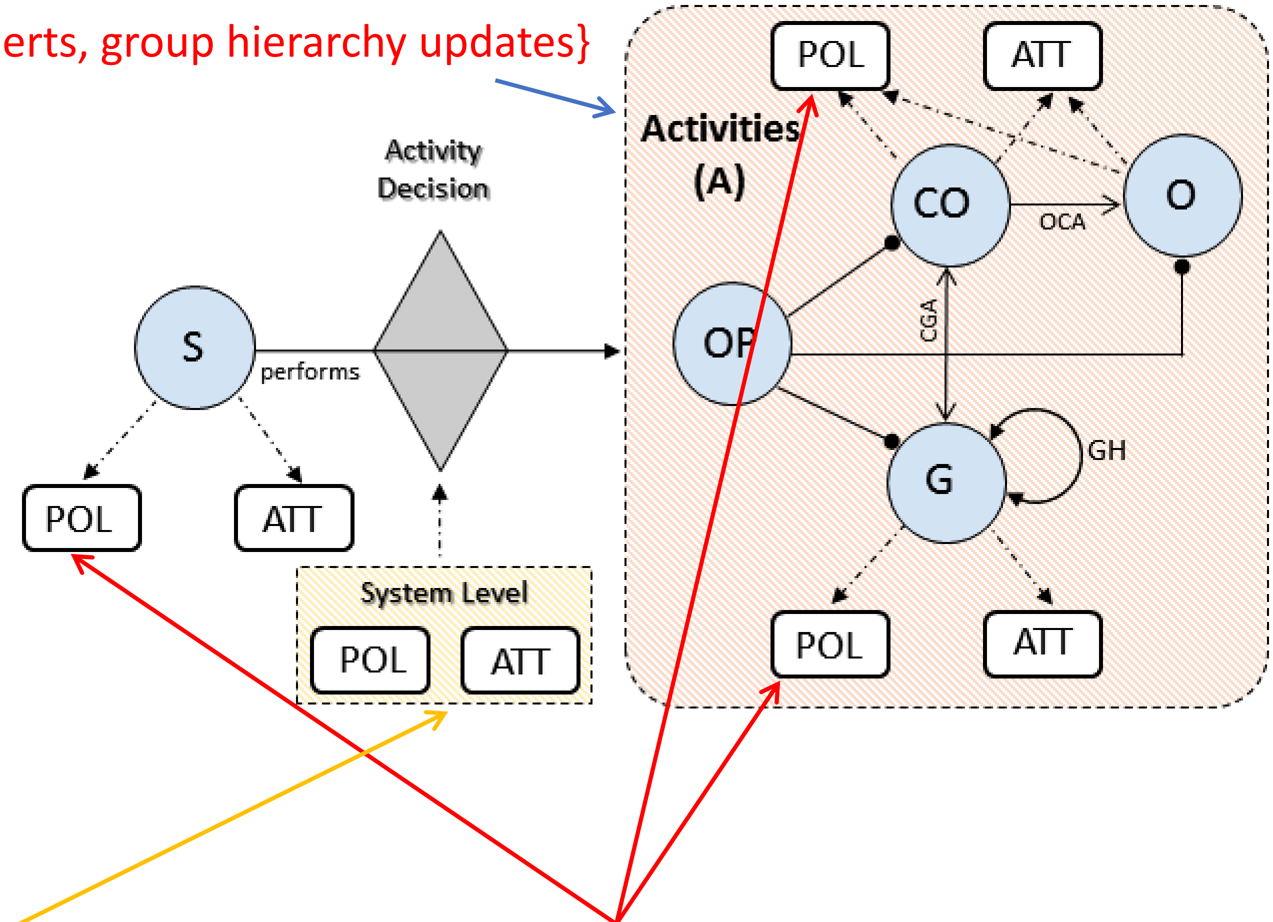
Model Components



Model Components

Operational and Administrative Activities

{notification, alerts, group hierarchy updates}



System Wide Policies

Individualized Privacy Policies

Formal Specification

Basic Sets and Functions

– S, CO, O, G, OP are finite sets of sources, clustered objects, objects, groups and operations respectively [blue circles in Figure 4].
– A is a finite set of activities which can be performed in system.
– ATT is a finite set of attributes associated with S, CO, O, G and system-wide.
– For each attribute att in ATT, Range(att) is a finite set of atomic values.
– attType: ATT = {set, atomic}, defines attributes to be set or atomic valued.
– Each attribute att in ATT maps entities in S, CO, O, G to attribute values. Formally,

$$\mathrm{att} : S \cup CO \cup O \cup G \cup \{\text{system-wide}\} \rightarrow \begin{cases} \mathrm{Range(att)} \cup \{\perp\} & \text{if attType(att) = atomic} \\ 2^{\mathrm{Range(att)}} & \text{if attType(att) = set} \end{cases}$$

– POL is a finite set of authorization policies associated with individual S, CO, O, G.
– directG : CO $\rightarrow$ G, mapping each clustered object to a system group, equivalently CGA $\subseteq$ CO $\times$ G.
– parentCO : O $\rightarrow$ CO, mapping each object to a clustered object, equivalently OCA $\subseteq$ O $\times$ CO.
– GH $\subseteq$ G $\times$ G, a partial order relation $\geq_g$ on G. Equivalently, parentG : G $\rightarrow 2^G$, mapping group to a set of parent groups in hierarchy.

Attribute Function

Attribute Type

Attribute Mapping

Group Hierarchy

Formal Specification

Effective Attributes of Groups, Clustered Objects and Objects (Derived Functions)

– For each attribute att in ATT such that attType(att) = set:

- $effG_{att} : G \rightarrow 2^{Range(att)}$, defined as $effG_{att}(g_i) = att(g_i) \cup (\bigcup_{g \in \{g_j | g_i \geq_g g_j\}} effG_{att}(g))$.
- $effCO_{att} : CO \rightarrow 2^{Range(att)}$, defined as $effCO_{att}(co) = att(co) \cup effG_{att}(directG(co))$.
- $effO_{att} : O \rightarrow 2^{Range(att)}$, defined as $effO_{att}(o) = att(o) \cup effCO_{att}(parentCO(o))$.

– For each attribute att in ATT such that attType(att) = atomic:

- $effG_{att} : G \rightarrow Range(att) \cup \{\perp\}$, defined as $effG_{att}(g_i) = \begin{cases} att(g_i) & \text{if } \forall g' \in parentG(g_i).\ effG_{att}(g') = \perp \\ effG_{att}(g') & \text{if } \exists\ parentG(g_i).\ effG_{att}(parentG(g_i)) \neq \perp \text{ then select} \\ & \text{parent } g' \text{ with } effG_{att}(g') \neq \perp \text{ updated most recently.} \end{cases}$
- $effCO_{att} : CO \rightarrow Range(att) \cup \{\perp\}$, defined as $effCO_{att}(co) = \begin{cases} att(co) & \text{if } effG_{att}(directG(co)) = \perp \\ effG_{att}(directG(co)) & \text{otherwise} \end{cases}$
- $effO_{att} : O \rightarrow Range(att) \cup \{\perp\}$, defined as $effO_{att}(o) = \begin{cases} att(o) & \text{if } effCO_{att}(parentCO(o)) = \perp \\ effCO_{att}(parentCO(o)) & \text{otherwise} \end{cases}$

Attributes more Dynamic

Attributes Inheritance

Policy Language

Authorization Functions (Policies)

– Authorization Function: For each op ∈ OP, $\text{Auth}_{op}(s : S, ob : CO \cup O \cup G)$ is a propositional logic formula returning true or false, which is defined using the following policy language:

- $\alpha ::= \alpha \wedge \alpha \mid \alpha \vee \alpha \mid (\alpha) \mid \neg\alpha \mid \exists\, x \in \text{set}.\alpha \mid \forall\, x \in \text{set}.\alpha \mid \text{set} \vartriangle \text{set} \mid \text{atomic} \in \text{set} \mid \text{atomic} \notin \text{set}$
- $\vartriangle ::= \subset \mid \subseteq \mid \not\subseteq \mid \cap \mid \cup$
- set ::= $\text{eff}_{\text{att}}(i) \mid \text{att}(i)$ — for att ∈ ATT, $i \in S \cup CO \cup O \cup G \cup$ {system-wide}, attType(att) = set
- atomic ::= $\text{eff}_{\text{att}}(i) \mid \text{att}(i) \mid$ value — for att ∈ ATT, $i \in S \cup CO \cup O \cup G \cup$ {system-wide}, attType(att) = atomic

❖ Administrators in the police department can send alert to location-groups in city limits.

$\text{Auth}_{\text{alert}}$(u:U, g:G) :: dept (u) Police ∧ parent-city(g) = Austin ∧
Austin ∈ jursidiction (u).

❖ Only mechanic in the technician department from Toyota-X dealership must be able to read sensor in Camry LE. Further, this operation must be done between time 9 am to 6 pm.

$\text{Auth}_{\text{read}}$(u:U, co:CO) :: role (u) Technician ∧ employer(u) = Toyota-X ∧
make (co) = Toyota ∧ model(co) = Camry LE ∧
operation_time(u) ∈ {9am,10,11…6pm}

I·C·S The Institute for Cyber Security

Activity Authorization Decision

C·SPECC Center for Security and Privacy Enhanced Cloud Computing

Authorization Decision

– A source $s \in S$ is allowed to perform an activity $a \in A$, stated as Authorization($a : A, s : S$), if the required policies needed to allow the activity are included and evaluated to make final decision. These multi-layer policies must be evaluated for individual operations ($op_i \in OP$) to be performed by source $s \in S$ on relevant objects ($x_i \in CO \cup O \cup G$).

$$\boxed{\text{Formally, Authorization}(a : A, s : S) \Rightarrow \text{Auth}_{op_1}(s : S, x_1), \text{Auth}_{op_2}(s : S, x_2), \ldots\ldots\ldots\ldots, \text{Auth}_{op_n}(s : S, x_3)}$$

Evaluate all relevant policies to make a decision

A restaurant in group A must be allowed to send notifications to all vehicles in location group A and group B.

System defined

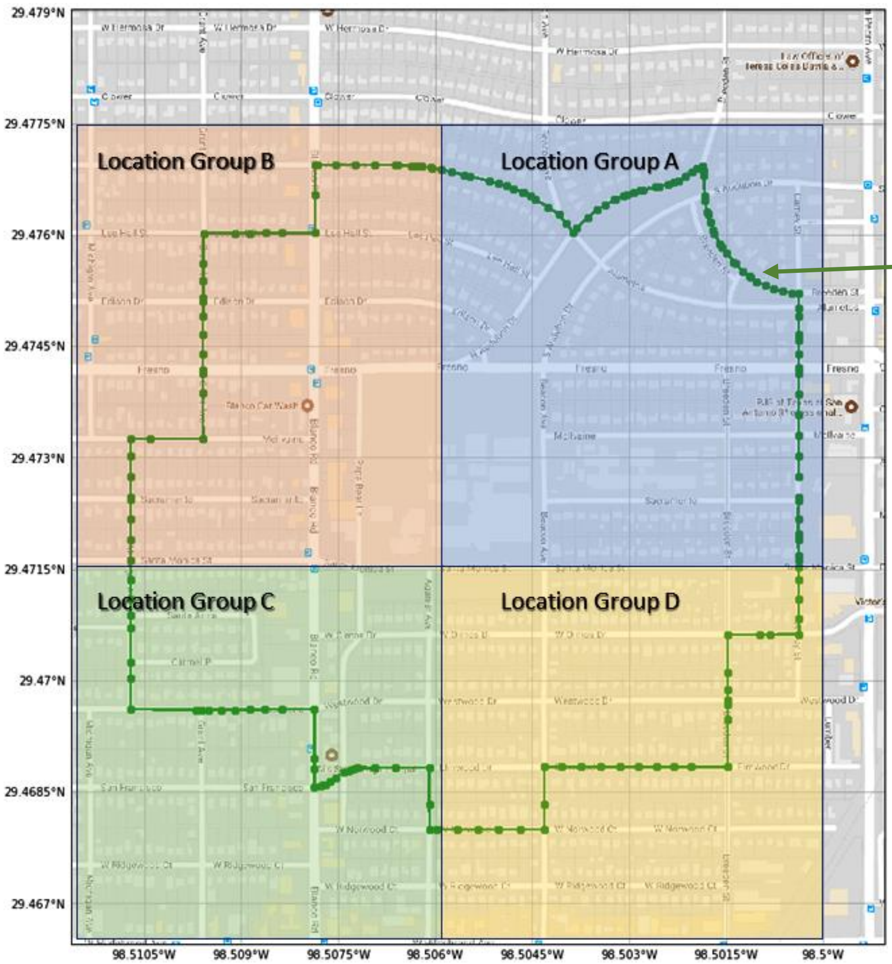
DECISION

User Preference

I only want notifications from Cheesecake factory.

Implementation in Amazon Web Services (AWS)

Vehicles and Groups



4 Location Groups (static demarcation)

Vehicles movement (coordinates generated using Google API)

```
('Received new coordinates from:', 'Vehicle-1')
Sun May 27 02:56:30 2018
  Location A
      Car-A : [u'Vehicle-1', u'Vehicle-2']
      Bus-A : []
  Location B
      Car-B : []
      Bus-B : [u'Vehicle-6']
  Location C
      Car-C : [u'Vehicle-3', u'Vehicle-4']
      Bus-C : []
  Location D
      Car-D : []
      Bus-D : [u'Vehicle-5']
```

Snapshot (table keeps changing)

Implemented Policies

- Administrative Policy
  - Road side motion sensor with [id = 1] and current GPS in group [Location-A] can only [modify] attribute [Deer Threat] to value [ON, OFF] for group [Location-A].

- Operational Policy

Restaurant Notification Use Case

System Defined Policy

- A restaurant located within group [Location-A] can only [send notifications] to members of groups [Location-A, Location-B].

User Preferences

- Send notifications only between [7 pm to 9 pm] only on [Wednesdays].

Performance Metrics

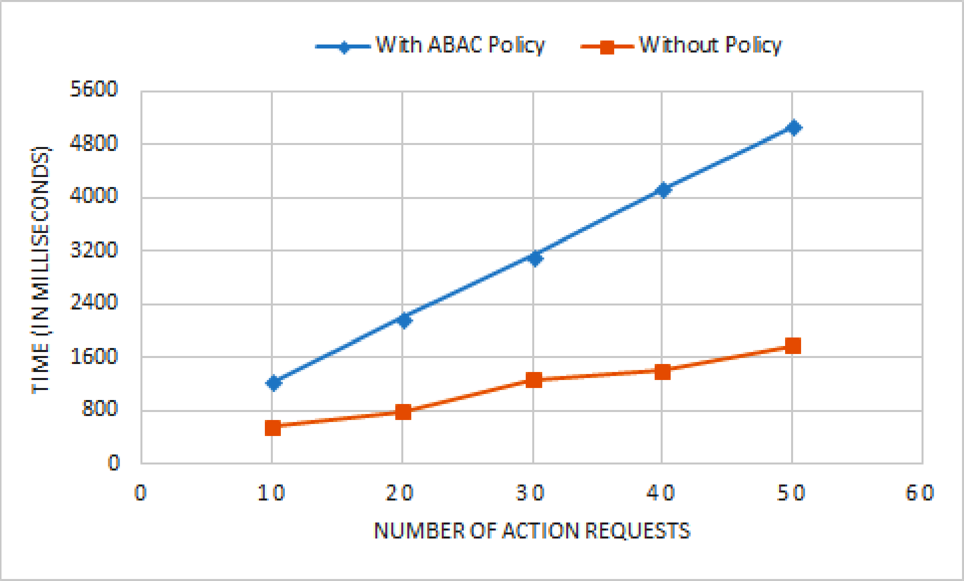
Number of Requests	Policy Enforcer Execution Time (in ms)
10	0.0501
20	0.1011
30	0.1264
40	0.1630
50	0.1999

Policy Enforcement Time

	CARS NOTIFIED	
n^{th} Request	With ABAC Policy	Without Policy
41^{st}	2	5
42^{nd}	3	5
43^{rd}	5	5
44^{th}	3	5
45^{th}	2	5
46^{th}	3	5

Relevance of Alerts and Notifications

Performance Metrics



Comparing Policy vs No Policy Execution Time

Conclusion and Future Work

- Proposed an Attribute Based Access Control solution for cloud assisted Smart Cars.
  - Introduced Dynamic Groups
  - Supports User Privacy Preferences and Location Centric
  - Proof of Concept implementation in AWS

- Future Research
  - Extensive and detailed evaluation
  - V2V and V2I secure trusted communication using Edge
  - Location preserving approaches

Thank You..!!

Questions, Comments or Concerns

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