

# Property Graph Type System and Data Definition Language

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## Revision Items

- **Replace Secondary Key terminology with Discriminator:** for edges that share the same pair of source and target vertices, the user can define a discriminator to further differentiate the edges. E.g. the employment date of a work\_for edge type is a **discriminator** if we wish to allow a person to work for the same company for multiple time spans in their career
- Clarify the meaning of **CASCADE** keyword: when dropping a vertex type V, without CASCADE keyword, an error will be raised if there is an edge type E referencing this vertex type V. With CASCADE keyword, E will be modified to reflect the disappearance of V. When the source types (or the target types) of E mention only V, then E is dropped.

## Abstract

This paper propose a type system to model property graph. In previous paper [YTZ-033] and [YTZ-034], labels are associated with properties, and a set of labels determine the properties of a vertex or an edge. In our proposal, we use the terminology “type” for pre-defined schema. And keep label its tag semantics. In addition, we introduce the inheritance concept to make our type system more flexible. DDL examples are provided to implement the model.

## Reference

[YTZ-033] Jan Michels, “The Property Graph Data Model”, ISO/IEC JTC1/SC32 WG3:YTZ-033 = ANSI INCITS DM32.2-2018-00091 / sql-pg-2018-0002

[YTZ-034] Neo4j SQL working group, “Property Graph Data Model for SQL”, ISO/ IEC JTC1/SC32 WG3:

## 1 Introduction

We define a type system used to model property graph. Based on the type system, we propose the associated data definition language (DDL).

Various places are different from [YTZ-033] and [YTZ-034]. A list of them includes

- Edge type has default primary key, and can add discriminator only when necessary
- Edge can have reverse edge, same schema and data, different direction and name
- Labels are purely tag, attachable to any group of graph elements
- Type can have inheritance

## 2 Property Graph

A property graph is a directed graph consists of vertices and edges. Each vertex and edge can have <property, value> pairs. It is a multi-graph, meaning between two vertices, there can be multiple edges. Labels can be attached to vertices and edges, and they serve as tags.

The traditional property graph is schema-less with the benefits of great flexibility— vertex or edge instances can be labeled freely, and the properties of them can be expanded or shrunk independently of each other.

The drawback of the schema-less style is data dependency. Application written based on labelling and property map can only work when the developer knows the data. For example, if data ingestion developer is independent of the application developer, then the application developer has no way to know what's ingested (label, properties) for each graph element, thus the data dependency problem. Another problem of schema-less is that it misses the opportunity of compressing more data. With a pre-defined schema, metadata and binary data are separated, and binary data can easily be compressed since each data record is structured.

We define a type system to make a property graph schema-based.

## 3 Property Graph Type System

In TigerGraph system, we define a property graph as a collection of typed vertices and the collection of typed edges that connect the vertices. By typed, we mean there is a user pre-defined schema for each vertex/edge type. Also, an edge type can be directed or undirected. Between two vertices, there can be multiple edges, and these edges can be of the same type or different types.

Note that readers should not be confused between the *type* and *schema object* concepts. They are different.

- **Type** is a set of rules that can be named and assign to a programming construct, such as an object, a chunk of binary.

- **Schema object** is created by DDL and resides in the catalog. Usually, the CREATE DDL create both a type and a schema object of the new type.

Each of the vertices and edges is of certain pre-defined type. This section describes the type system used to model a property graph. Namely, there are vertex type, edge type, graph type, and label type. Vertex types and edge types are the building block of a graph type. Label type is a semantic tag attachable to any graph elements.

## 3.1 Vertex Type

A vertex type is used to describe the schema<sup>1</sup> of a class of vertex entities. It must have

- a type name: an unique identifier.
- a set of attributes (non-empty, at least one attribute serves as the primary key): each attribute has a name and its associated data type. The data type can be any ISO SQL data type, and container type (such as as Map<K,V>, List<T>, Set<T>, and Order<T> etc., where T is the element type).
- a primary key: one or more attributes that can uniquely identify a vertex of this type.
- a built-in label attribute, which encodes the labels (see 3.4).

Optionally, a vertex type can have an auto-assigned primary key

- UUID. see [https://en.wikipedia.org/wiki/Universally\\_unique\\_identifier](https://en.wikipedia.org/wiki/Universally_unique_identifier) Using UUID can avoid guessing the size of a vertex type, and also has the least leakable information.

## 3.2 Edge Type

An edge type is used to describe the schema of a class of edge entities. It must have

- a type name: an unique identifier.
- a set of attributes (possibly empty): each attribute has a name and its associated data type. The data type can be any ISO SQL data type, and container type (such as as Map<K,V>, List<T>, Set<T>, and Order<T> etc., where T is the element type).
- one or more pairs of source vertex type and target vertex type.
- direction property: *directed* or *undirected*. If the edge type is directed, it means the edge type models an asymmetric relationship, where the edge instance always starts from a source vertex and ends at a target vertex to capture the one direction semantics. If the edge type is undirected, it models a symmetric relationship between the source and target vertex types.
- a built-in label attribute, which encodes the labels (see 3.4).

Optionally, an edge type may further have

- a **discriminator**, a set of attributes that allows this distinction to be made when two edges share the same pair of source and target vertex instances . By default, the source vertex and target vertex's primary keys are used to uniquely identify an edge instance.

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<sup>1</sup> Schema refers to the organization of data as a blueprint of how the database element is constructed.

However, sometime the same edge type instances appear more than once between two vertices, a **discriminator** will help further distinguish them.

- a reverse edge type: if the edge type is specified as directed, a reverse edge type shares the same schema as the forward edge type, except the direction of it is opposite to the forward edge; and reverse edge type has a unique name. This reverse edge type will enhance readability and provide more explicitly meaning of query traversal.

## 3.3 Graph Type

A graph type specifies a collection of vertex types and edge types that collectively depicts the graph schema. It must have

- a name: an unique identifier.
- zero or more vertex types.
- zero or more edge types: if an edge type is included in a graph type, its source and target vertex types must be included in the graph's vertex type collection.
- a built-in label attribute, which encodes the labels (see 3.4).

Note that when there is zero vertex types and edge types, it means an empty graph type with a user specified name. Sometimes, this is useful to reserve a graph namespace before user wants to add any next level types.

## 3.4 Label Type

Labels are semantic tag to graph *data elements*. It has

- a name: an unique identifier
- a description (optional): a string to describe its meaning, could be empty.

This is useful when user want to persist clustering or classification result without changing the vertex, edge or graph types.

## 3.5 Type Inheritance

For each of the above type, we allow type inheritance. Each type can have subtypes. Each subtype can only have one super type (except label type).

### 3.5.1 Vertex Type Inheritance

A vertex type can be derived from another vertex type. For example, a professor is a sub vertex type, extended from the person super vertex type. A sub vertex type can only inherit one super vertex type. The sub vertex type will

- Inherit all of the super vertex type attributes
- Share the same primary key of the super type. This is important to support polymorphism. In graph database, a unique identifier is important to identify an object of

a particular type. To support using super type to do polymorphism, a shared primary key between the super type and its descendant types is a must.

- When the super type attributes are changed in the super type, all descendant types' attributes are changed accordingly.
- The super type attributes cannot be changed directly in its descendant subtype.

### 3.5.2 Edge Type Inheritance

An edge type can also have subtypes. The sub type will

- Inherit all the super edge type attributes.
- Inherit the pairs of source vertex type and target vertex type.
- Inherit the direction property.
- Inherit the discriminator if there is one.
- Create the reverse edge type with a different name.
- When the super type attributes are changed in the super type, all descendant types' attributes are changed accordingly.
- When the super type's source and target vertex type pairs are changed in the super type, all descendant types' are changed accordingly.
- The super type attributes and (source, target) vertex pairs cannot be changed directly in the subtype.

### 3.5.3 Graph Type Inheritance

A graph can also have subtypes. The subtype will

- Inherit all the vertex types and edge types in the super graph type.
- When any types contained in the super graph type change, the subgraph type changes accordingly.
- The super graph's vertex and edge types cannot be changed directly in the sub graph type.

### 3.5.4 Label Type Inheritance

A label can also have subtypes. The subtype will form an inheritance relationship with the super type. A label sub type can inherit multiple super types.

## 4 DDL for the Property Graph Model

With the above graph type system, we are ready to discuss the DDL to create schema objects. In this section, we only list the syntax by example. The actual EBNF rule can be found in the Appendix section.

DDL reserved keyword is case insensitive. User specified identifier is case sensitive. However, for ease of presentation, we use upper case on keyword, and lower case on user specified identifier. Here we focus on illustrating the syntax.

## 4.1 Create Statement

A CREATE statement will create a schema object, and a schema type. The schema object will be stored in the database's catalog; its corresponding type is also created implicitly.

- create vertex

#a person schema object is created; its type is person vertex type.

```
CREATE VERTEX person (name STRING NOT NULL PRIMARY KEY, age INT, gender STRING, state STRING)
```

#another way to specify primary key

```
CREATE VERTEX person (first_name STRING NOT NULL, last_name STRING NOT NULL, age INT, gender STRING, state STRING, PRIMARY KEY(first_name, last_name))
```

#a professor schema object is created; its type is professor vertex type

#which is a subtype of person vertex type.

```
CREATE VERTEX professor EXTENDS person (position STRING)
```

- create edge

#an friendship schema object is created; its type is friendship edge type.

```
CREATE UNDIRECTED EDGE friendship (FROM person, TO person, connect_day DATETIME)
```

#supervise and supervised\_by are both created; their type is supervise and supervised\_by edge type, respectively.

```
CREATE DIRECTED EDGE supervise (FROM person, TO person, connect_day DATETIME) WITH REVERSE_EDGE="supervised_by"
```

```
CREATE DIRECTED EDGE supervise (FROM person, TO person, connect_day DATETIME, DISCRIMINATOR (connect_day))
```

```
WITH REVERSE_EDGE="supervised_by"
```

#a mentorship schema object is created; its type is mentorship edge type, which is a subtype of supervise

# edge type.

```
CREATE DIRECTED EDGE mentorship EXTENDS supervise(end_day DATETIME) WITH REVERSE_EDGE= "mentored_by"
```

- create graph

#below two graph schema objects are created. Both contain the same schema object of person vertex type.

```
CREATE GRAPH social (person, friendship)
CREATE GRAPH company (person, supervise)
```

#below, a graph facebook is created based on social, it has alumni edge type added.

```
CREATE UNDIRECTED EDGE alumni_relation (FROM person, TO person)
CREATE GRAPH facebook EXTENDS social (alumni_relation)
```

- create label

```
CREATE LABEL color Description "color super class"
CREATE LABEL car Description "car super class"
CREATE LABEL redcar EXTENDS color, car
```

## 4.2 Drop Statement

A DROP statement will remove a schema object, and its corresponding type from the catalog.

- When dropping a supertype A, an error is raised if there exists subtypes B of A.
- When dropping a subtype B, all data of supertype A stays.

- drop vertex

# **Cascade** Drop vertex type can use this option Cascade. When dropping a vertex type #V, without CASCADE keyword, an error will be raised if there is an edge type E #referencing this vertex type V. With CASCADE keyword, E will be modified to reflect #the disappearance of V. When the source types (or the target types) of E mention only #V, then E is dropped.

```
DROP VERTEX person CASCADE
DROP VERTEX person, city, school
```

#delete all vertex schema objects and their types

```
DROP VERTEX *
```

- drop edge

```
#drop the edge type and object
DROP EDGE friendship, supervise
```

```
DROP EDGE friendship
```

```
#delete all edge types
```



DROP EDGE \*

#delete all related source and target vertex objects

DROP EDGE \*

- drop graph  
#the graph type is dropped, but not the vertex/edge types it references.  
DROP GRAPH social

DROP GRAPH social, company

- drop label

DROP LABEL red

DROP LABEL color

## 4.3 Alter Statement

An ALTER statement will change a schema object and its type.

- alter vertex add/drop attributes

ALTER VERTEX person ADD (ssn VARCHAR(9))

ALTER VERTEX person DROP (ssn VARCHAR(9))

- alter edge add/drop attributes

ALTER EDGE friendship ADD (location VARCHAR(20))

ALTER EDGE friendship DROP (location VARCHAR(20))

- alter graph add/drop vertex type and edge type

ALTER GRAPH school ADD VERTEX (professor, student)

ALTER GRAPH school DROP VERTEX (professor)

#note below, it **implicitly** add all referencing source vertex type and target vertex type  
#into the graph

ALTER GRAPH school ADD EDGE (teach\_class)

#only drop edge type

ALTER GRAPH school DROP EDGE (teach\_class)

#note below, it will drop all dependent source vertex type and target vertex type from the graph.

ALTER GRAPH school DROP EDGE (teach\_class)

## 5 Map To Relational Table

Since we have defined the type system, the type relationships will be stored in the catalog as they are created by DDLs, the only thing left to specify is how to map the schema object to relational schema object.

### 5.1 Vertex Schema Object

Vertex schema object can be directly mapped to a relational table due to its structure design. Add a label column, its type could be string or other type that can store multiple labels.

### 5.2 Edge Schema Object

Edge schema object can be mapped to a relational table by doing the following:

- FROM vertex type: add the columns corresponds to the primary key of the FROM vertex type.
- TO vertex type: add the columns corresponds to the primary key of the TO vertex type.
- Attributes: add the remaining columns for the edge attributes.
- Add a label column, its type could be string or other type that can store multiple labels.

## Appendix

```
CREATE_QB ::= 'create' (CREATE_VERTEX_QB | CREATE_EDGE_QB |  
                      CREATE_GRAPH_QB | CREATE_LABEL_QB)
```

```
CREATE_VERTEX_QB ::= 'vertex' IDENTIFIER '(' ATTRIBUTE_ELEMENT ('  
                      ATTRIBUTE_ELEMENT)* (, 'primary' 'key' ('  
                      IDENTIFIER (,IDENTIFIER)*'))? ')'
```

```
CREATE_EDGE_QB ::= ('directed' |'undirected') 'edge' IDENTIFIER '(' 'from' ((IDENTIFIER  
                      (|' IDENTIFIER*)|STAR) ',' 'to' ((IDENTIFIER (|' IDENTIFIER)*  
                      )|STAR) (' ATTRIBUTE_ELEMENT)* ')'  
                      ('WITH' KEY_VAL_SUFFIX)?
```

```
CREATE_GRAPH_QB ::= 'graph' IDENTIFIER '(' IDENTIFIER (',' IDENTIFIER)* ')'
```

```
CREATE_LABEL_QB ::= 'label' IDENTIFIER (DESCRIPTION STRING_LITERAL)?
```

```
DROP_QB ::= 'drop' DROP_VERTEX_QB | DROP_EDGE_QB | DROP_GRAPH_QB |
```

## DROP\_LABEL\_QB

DROP\_VERTEX\_QB ::= 'vertex' IDENTIFIER (, IDENTIFIER)\* 'cascade'?

DROP\_EDGE\_QB ::= 'edge' IDENTIFIER (, IDENTIFIER)\*

DROP\_GRAPH\_QB ::= 'graph' IDENTIFIER (, IDENTIFIER)\*

DROP\_LABEL\_QB ::= 'label' IDENTIFIER (, IDENTIFIER)\*

ALTER\_QB ::= 'alter' (ALTER\_VERTEX\_QB | ALTER\_EDGE\_QB|ALTER\_GRAPH\_QB)

ALTER\_VERTEX\_QB ::= 'vertex' IDENTIFIER (ALTER\_ADD\_VERTEX\_PROP\_QB |  
ALTER\_UPDATE\_VERTEX\_PROP\_QB | ALTER\_DROP\_VERTEX\_PROP\_QB)

ALTER\_EDGE\_QB ::= 'edge' IDENTIFIER (ALTER\_ADD\_EDGE\_PROP\_QB |  
ALTER\_UPDATE\_EDGE\_PROP\_QB | ALTER\_DROP\_EDGE\_PROP\_QB)