Data Models for the Cloud

Relational Model Shortcomings

- Greater Scalability
  - High write throughput / very large datasets
- Independence of few vendors — Move towards Open Source
- Need for different query operations
- Restrictiveness of relational schemas

Alternatives to Relational Schemes: XML

- Data is often structured hierarchically

```
Invoice = {
  date : "2008-05-24"
  invoiceNumber : 421

  InvoiceItems : {
    Item : {
      description : "Wool Paddock Shet Ret Double Bound Yellow 4'0"
      quantity : 1
      unitPrice : 105.00
    }
    Item : {
      description : "Wool Race Roller and Breastplate Red Double"
      quantity : 1
      unitPrice : 75.00
    }
    Item : {
      description : "Paddock Jacket Red Size Medium Inc Embroidery"
      quantity : 2
      unitPrice : 67.50
    }
  }
}
```

Alternatives to Relational Schemes: XML

- Example as a relational scheme
  - `Invoice_Items(invoice.id, description, quantity, unit_price)`
  - `Invoices(date, invoice.id)`

Alternatives to Relational Schemes: XML

- As an XML document

```xml
<invoice>

 <number>421</number>
 <date>2008-05-24</date>
 <items>
  <item>
   <description>Wool Paddock Shet Ret Double Bound Yellow 4'0"</description>
   <quantity>1</quantity>
   <unitPrice>105.00</unitPrice>
  </item>
  <item>
   <description>Wool Race Roller and Breastplate Red Double</description>
   <quantity>1</quantity>
   <unitPrice>75.00</unitPrice>
  </item>
  <item>
   <description>Paddock Jacket Red Size Medium Inc Embroidery</description>
   <quantity>2</quantity>
   <unitPrice>67.50</unitPrice>
  </item>
 </items>
</invoice>
```

Alternatives to Relational Schemes: XML

- Advantage of XML
  - Faster to scan
  - Less need for joins
- Disadvantages of XML
  - Each record contains the full or an abbreviated scheme

Alternatives to Relational Schemes: JSON

- JSON — JavaScript Object Notation
    - Human-readable
    - Organized as key-value pairs

Alternatives to Relational Schemes: JSON

- JSON record example


```json
{
  "firstName": "John",
  "lastName": "Smith",
  "isAlive": true,
  "age": 27,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021-3100"
  },
  "phoneNumbers": [
    {
      "type": "home",
      "number": "212 555-1234"
    },
    {
      "type": "office",
      "number": "646 555-4567"
    },
    {
      "type": "mobile",
      "number": "123 456-7890"
    }
  ],
  "children": [],
  "spouse": null
}
```

Alternatives to Relational Schemes: JSON

- JSON can use a schema (type definition)
- JSON was first used for data transmission as a data serialization format

Alternatives to Relational Schemes: JSON

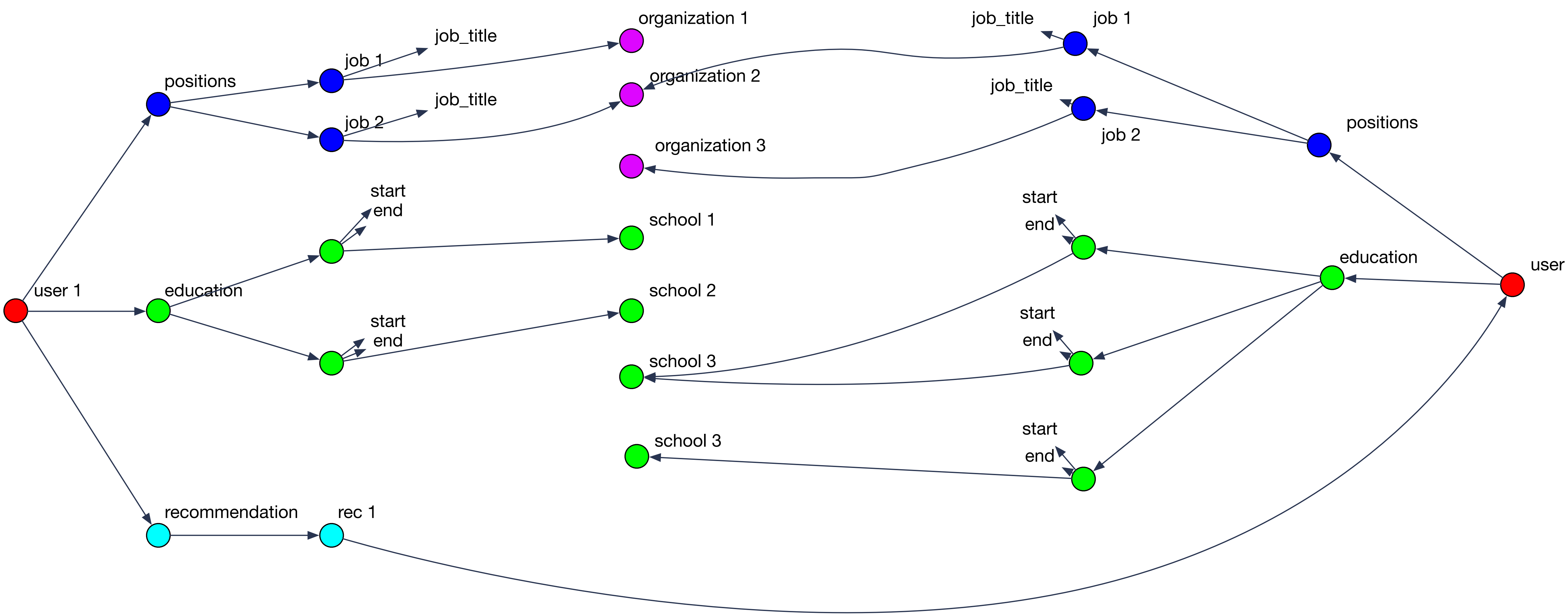
- Many-to-One and Many-to-Many Relationships
  - Modeled by the same value for the same key
    - Problem: Need to standardize / internationalize these values
    - Using id-s instead of plain text to avoid problems
    - Table of id-s reintroduce a relational scheme through a backdoor

Alternatives to Relational Schemes: JSON

- Resumé
  - Users present people
  - People have jobs, education, and recommenders
- But they share jobs, companies, degrees, schools, recommenders
  - Should they stay text strings or become entities?
    - Latter allows to add information to all resumés
- If recommenders get a photo, then all resumés should be updated with this photo, so better to make recommenders entities

Alternatives to Relational Schemes: JSON

- Data has a tendency to become less-join free



Document Databases

- Records are documents
  - Encode in
    - XML
    - YAML
    - JSON
    - BSON (Mongo DB)
  - CRUD operations: create, read, update, delete

Document Databases

- Enforcing schema
  - Most document databases do not enforce schema
    - —> “Schemaless”
    - In reality: “Schema on Read”
    - RDBMS would then use “Schema on Write”
- Allows schema updates in simple form

Document Databases

- Schema on Read:
  - Advantages:
    - Data might come from external sources
  - Disadvantages:
    - No data checking

Document Databases

- Document database support
  - Most commercial database systems now support XML databases

Query Languages

- Documents lend themselves to object-oriented querying
  - Imperative code
- SQL is declarative:
  - Programmer explains a solution
  - System figures out the best way to find the solution
- Use declarative query languages for document databases

Query Languages

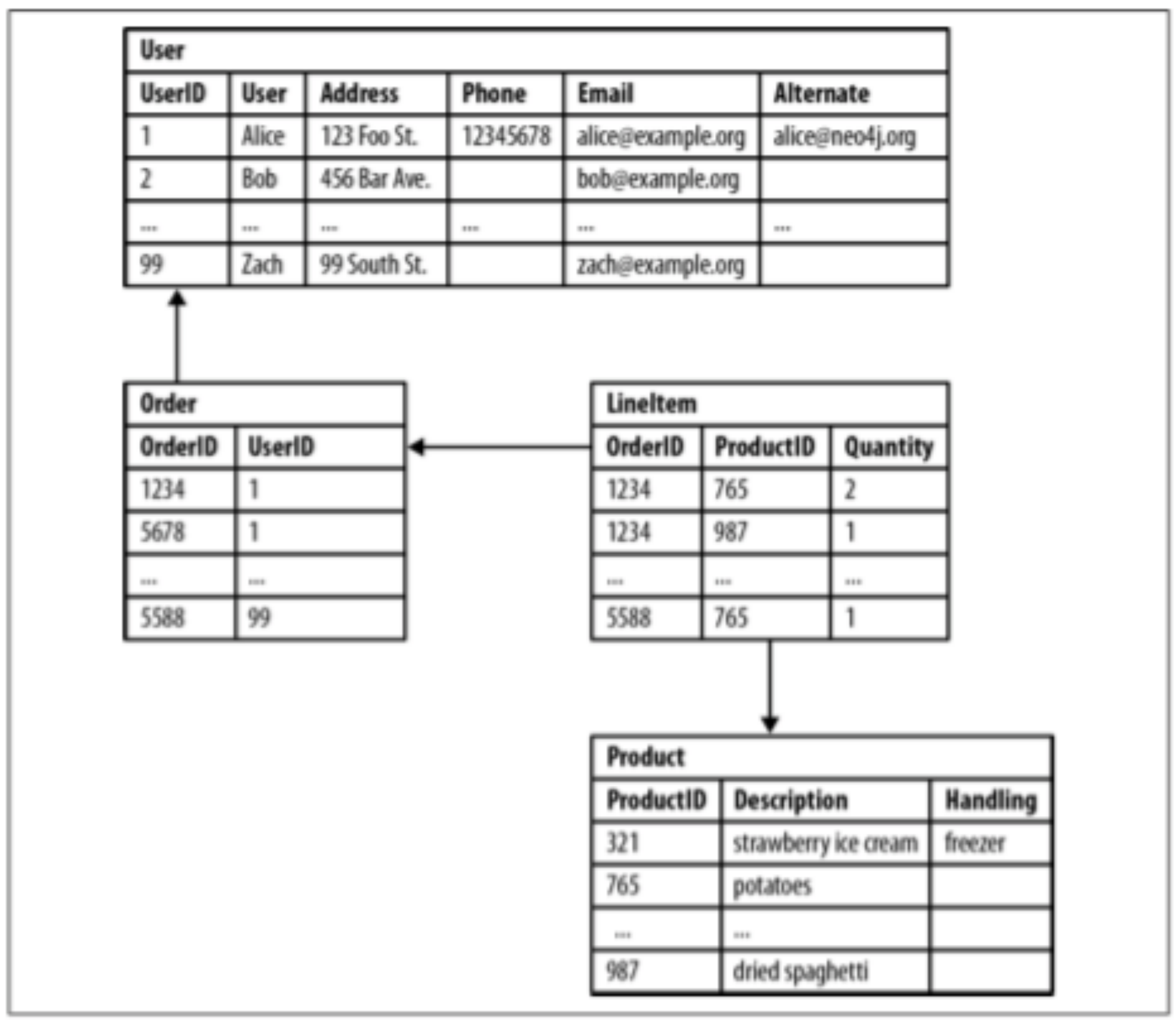
- Map-Reduce (neither declarative nor imperative):
  - Consists of only two pieces of code
    - Mapping: Selecting from Documents
    - Reducing: Take selection elements and operate on them

Alternatives to Relational Schemes: Graph Models

- Graphs consists of vertices and edges
  - Example:
    - Social graphs: vertices are people and edges are relationships such “knows”
    - Web graph: vertices are pages and edges are links
    - Road networks: vertices are places and edges are connections

Alternatives to Relational Schemes: Graph Models

- Relational Database hides semantic relationships



User					
UserID	User	Address	Phone	Email	Alternate
1	Alice	123 Foo St.	12345678	alice@example.org	alice@neo4j.org
2	Bob	456 Bar Ave.		bob@example.org	
...	...	...	...	...	...
99	Zach	99 South St.		zach@example.org	

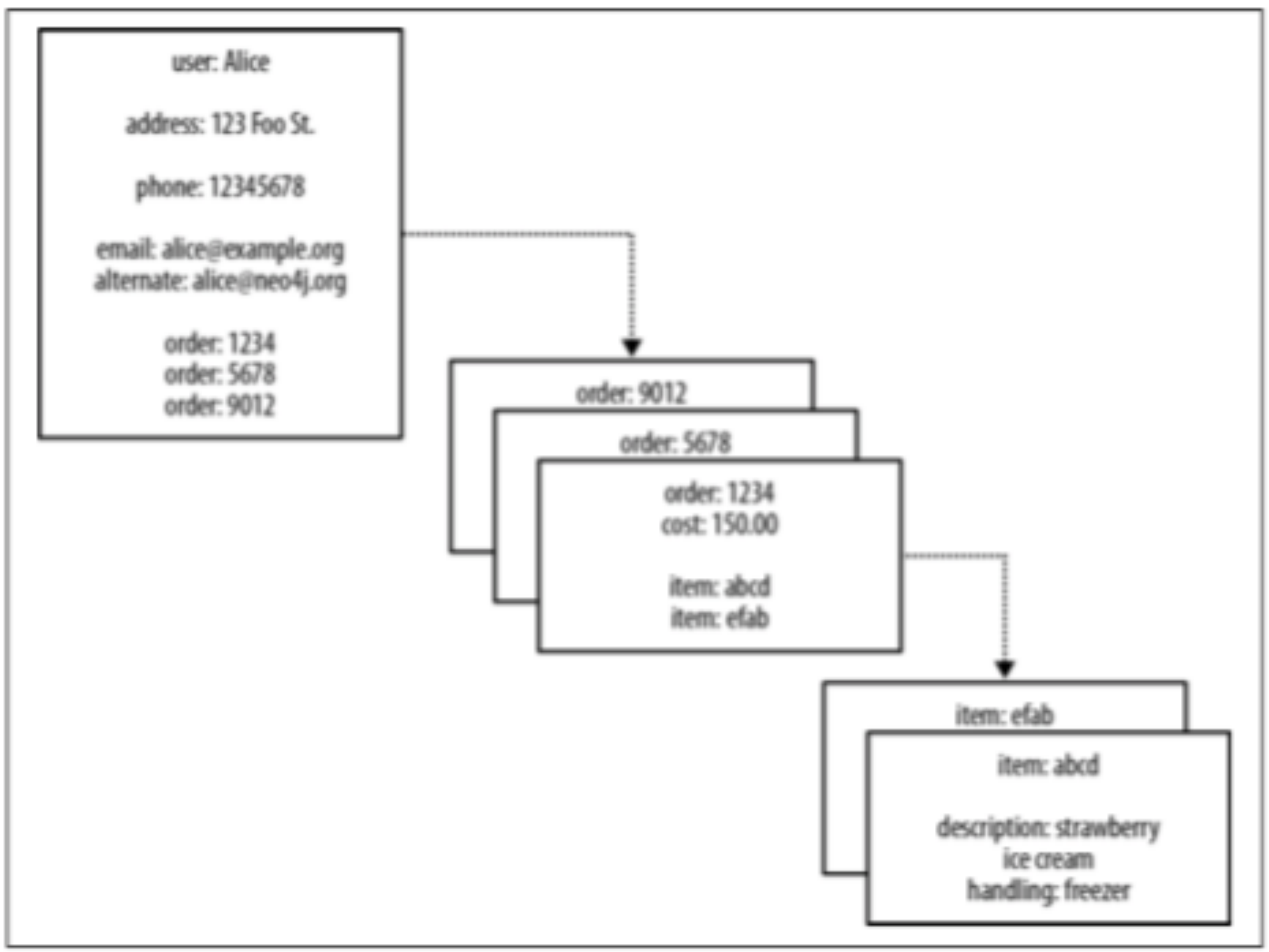
Order	
OrderID	UserID
1234	1
5678	1
...	...
5588	99

LineItem		
OrderID	ProductID	Quantity
1234	765	2
1234	987	1
...	...	...
5588	765	1

Product		
ProductID	Description	Handling
321	strawberry ice cream	freezer
765	potatoes	
...	...	
987	dried spaghetti	

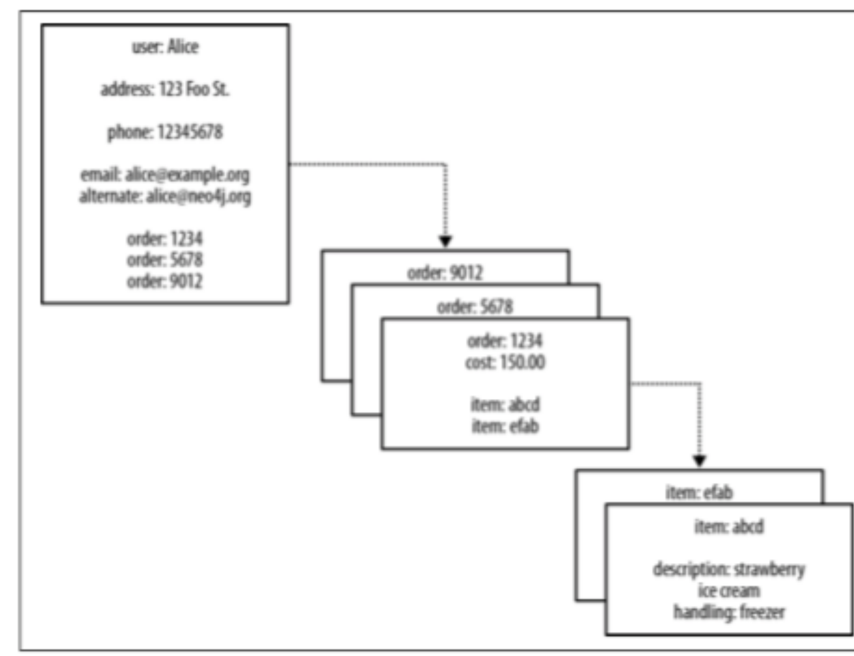
Alternatives to Relational Schemes: Graph Models

- Document model hides semantic relationships



Alternatives to Relational Schemes: Graph Models

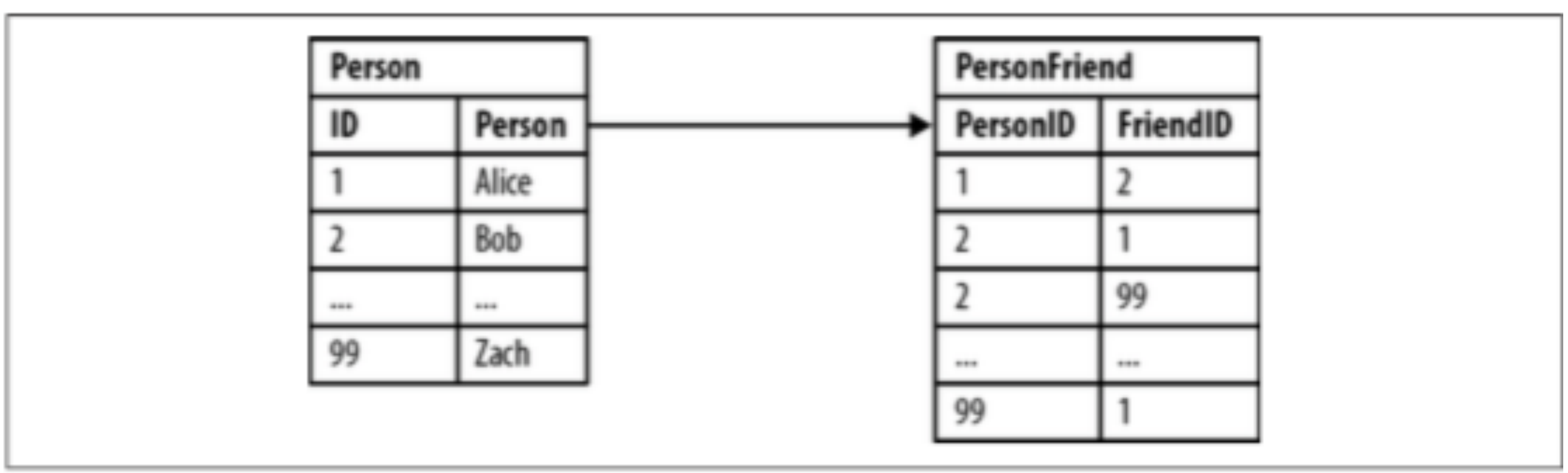
- Some property values are really references to foreign aggregates
  - Aggregate's identifier is a foreign key
- Relationships between them are not explicitly accessible
  - Joining aggregates becomes expensive



Alternatives to Relational Schemes: Graph Models

- Relational Database
  - Some queries are simple:

```
SELECT p1.Person
FROM Person p1 JOIN PersonFriend
ON PersonFriend.FriendID = p1.ID JOIN Person p2
ON PersonFriend.PersonID = p2.ID WHERE p2.Person = 'Bob'
```



Person	
ID	Person
1	Alice
2	Bob
...	...
99	Zach

PersonFriend	
PersonID	FriendID
1	2
2	1
2	99
...	...
99	1

Alternatives to Relational Schemes: Graph Models

- Relational Database
  - Some queries others are more involved: Friends of Bob

```
SELECT p1.Person
FROM Person p1 JOIN PersonFriend
   ON PersonFriend.PersonID = p1.ID JOIN Person p2
   ON PersonFriend.FriendID = p2.ID
WHERE p2.Person = 'Bob'
```

Person	
ID	Person
1	Alice
2	Bob
...	...
99	Zach

PersonFriend	
PersonID	FriendID
1	2
2	1
2	99
...	...
99	1

Alternatives to Relational Schemes: Graph Models

- Relational Database
  - Some queries others are difficult: Alice’s friends of friends

```
SELECT p1.Person AS PERSON, p2.Person AS FRIEND_OF_FRIEND FROM
PersonFriend pf1 JOIN Person p1
ON pf1.PersonID = p1.ID JOIN PersonFriend pf2
ON pf2.PersonID = pf1.FriendID JOIN Person p2
ON pf2.FriendID = p2.ID
WHERE p1.Person = 'Alice' AND pf2.FriendID <> p1.ID
```

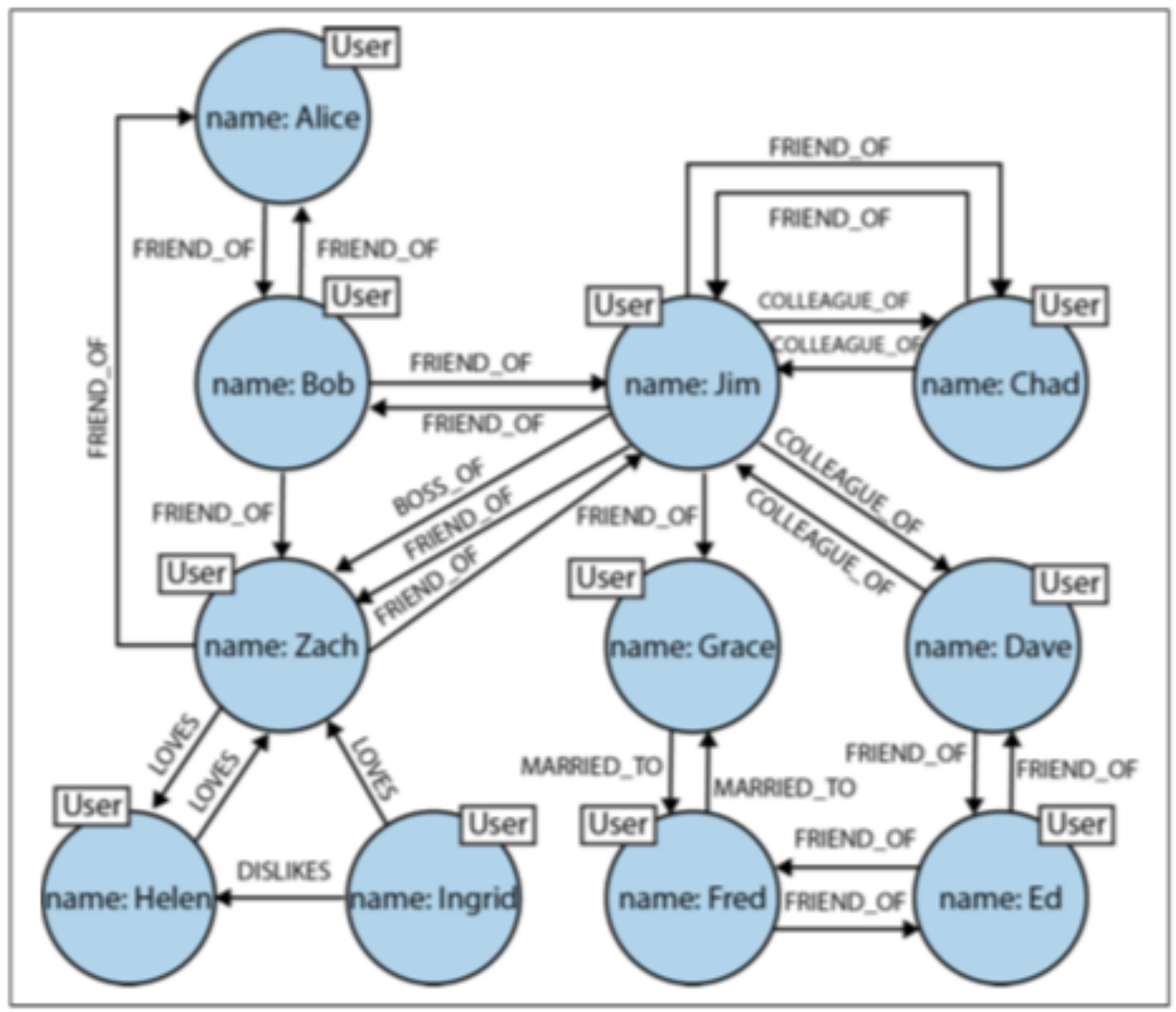
Person	
ID	Person
1	Alice
2	Bob
...	...
99	Zach

PersonFriend	
PersonID	FriendID
1	2
2	1
2	99
...	...
99	1

Alternatives to Relational Schemes: Graph Models

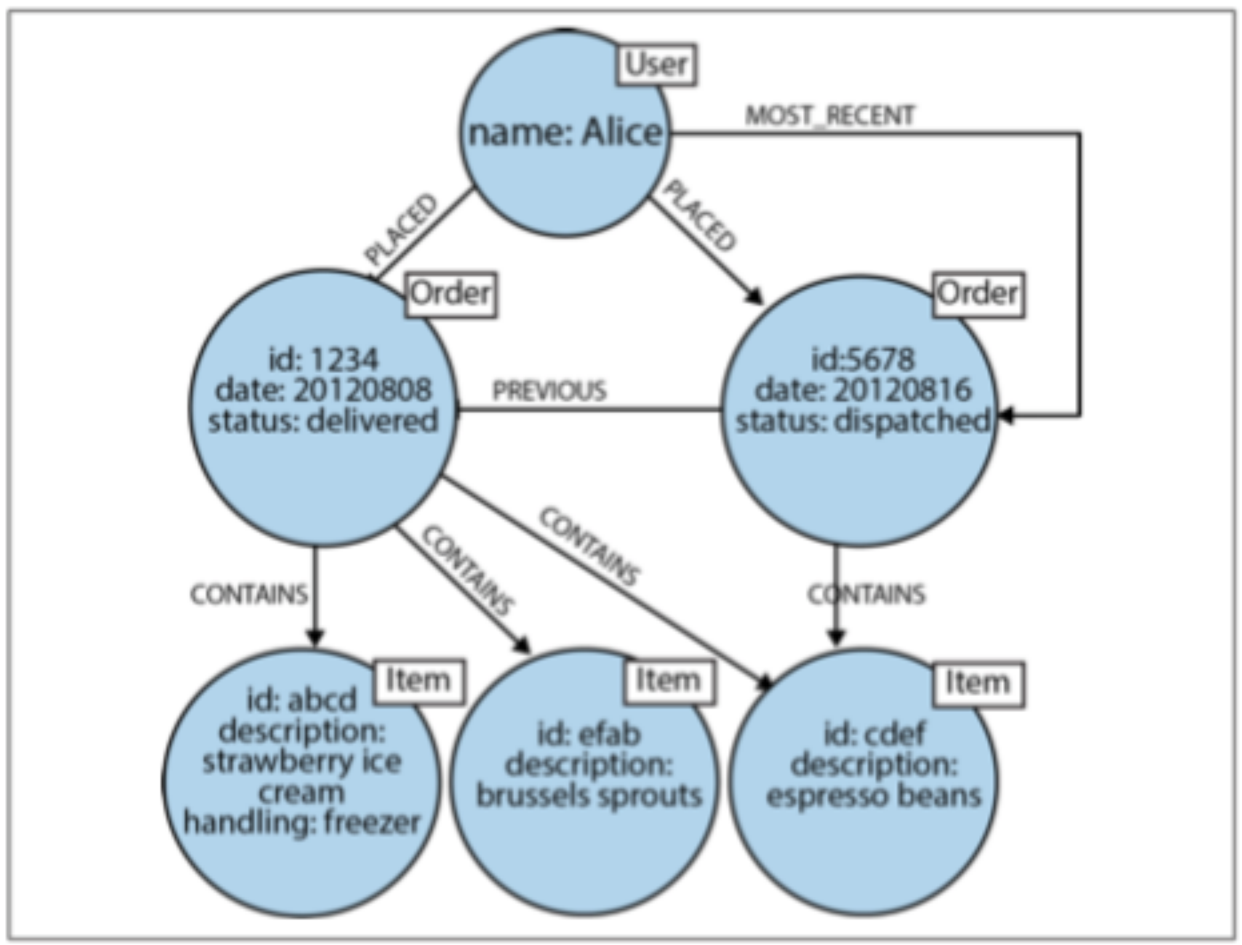
- Property graph model by Neon
  - Each vertex consists of
    - A unique identifier
    - A set of outgoing edges
    - A set of incoming edges
    - A collection of properties — key-value pairs
  - Each edge consists of
    - A unique identifier
    - The tail vertex
    - The head vertex
    - A label to describe the relationship
    - A collection of properties — key-value pairs

Alternatives to Relational Schemes: Graph Models



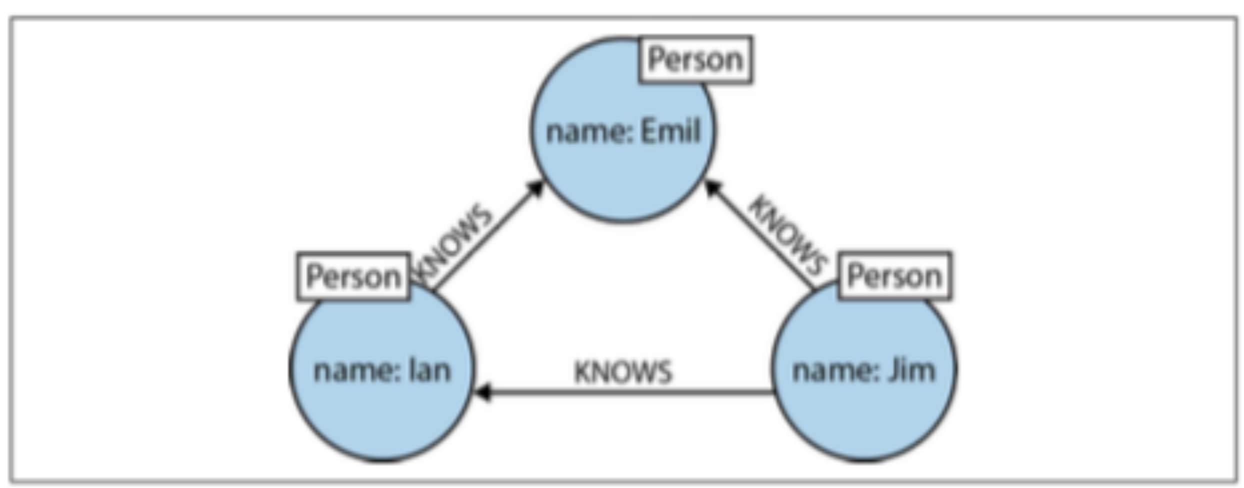
Alternatives to Relational Schemes: Graph Models

- Order history as a property graph



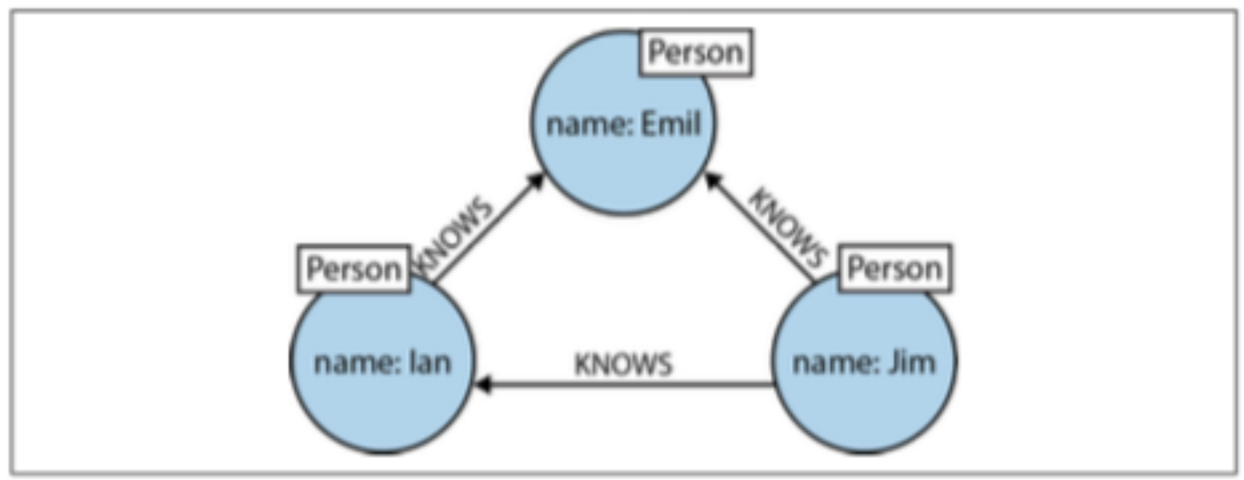
Alternatives to Relational Schemes: Graph Models

- Processing queries in Neo4j
  - Use Cypher (from "The matrix")
  - Can describe a path




```
(emil)<-[:KNOWS]-(jim)-[:KNOWS]->(ian)-[:KNOWS]->(emil)
```

Alternatives to Relational Schemes: Graph Models




```
(emil:Person {name:'Emil'})
      <-[:KNOWS]-(jim:Person {name:'Jim'})
      -[:KNOWS]->(ian:Person {name:'Ian'})
      -[:KNOWS]->(emil)
```

Alternatives to Relational Schemes: Graph Models

- Finding the mutual friends of Jim:

```
MATCH (a:Person {name:'Jim'})-[:KNOWS]->(b)-[:KNOWS]->(c), (a)-
[:KNOWS]->(c)
RETURN b, c
```

Alternatives to Relational Schemes: Graph Models

- Triple Stores

- Information is stored as (subject, predicate, object)
  - Subjects correspond to vertices
  - Objects are
    - A value in a primitive data type — (jim : age : **64**)
    - Another vertex — (jim : friend_of : thomas)

Alternatives to Relational Schemes: Graph Models

```
@prefix : </example>
_:lucy    a           :Person
_:lucy    :name       “Lucy”
_:lucy    :born_in    _:idaho
_:idaho   a           :Location
_:idaho   :name       “Idaho”
_:idaho   :type       “State”
_:idaho   :within     _:usa
```

Alternatives to Relational Schemes: Graph Models

- Triple stores are the language of the semantic web
- Semantic web:
    - Machine readable description of type of links
        - e.g. image, text, …
    - Creates web of data — a database of everything
- Stored in Resource Description Framework (RDF)
- SPARQL — query language for triple stores