

COMP5338 – Advanced Data Models

Week 8: Neo4j Internal and Data Modeling

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Outline

- **Neo4j Storage**

- Neo4j Query Plan and Indexing

- Neo4j – Data Modeling

- Neo4j – Graph Algorithms

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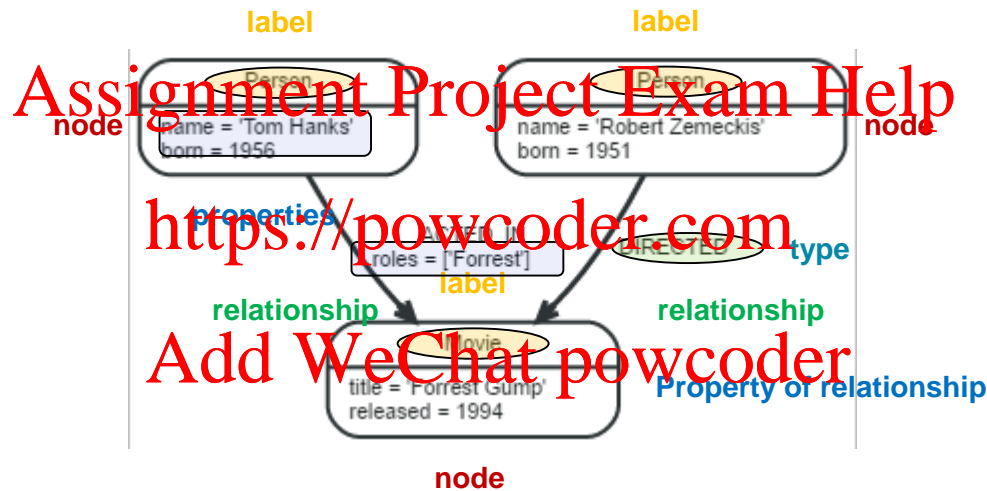
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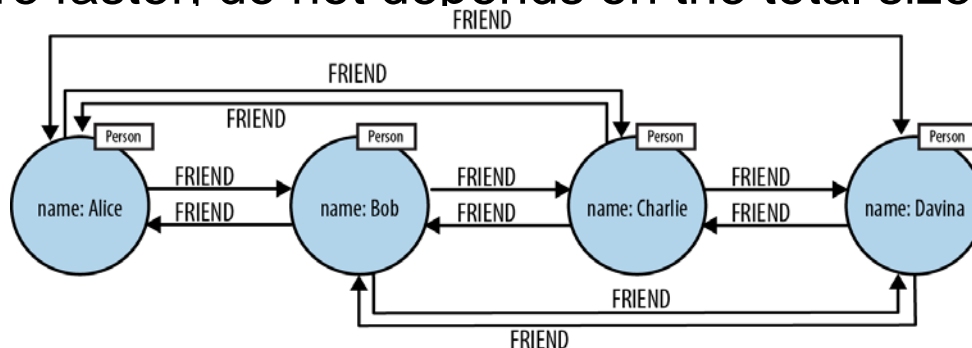
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Property Graph Model



Index-free Adjacency

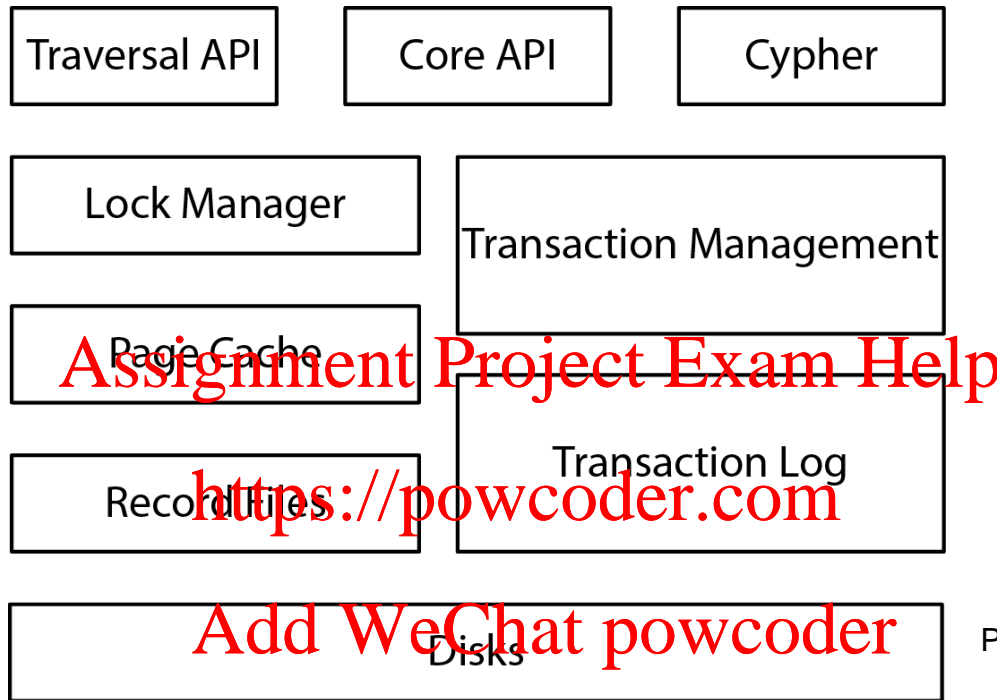
- Native storage of relationships between nodes
 - ▶ Effectively a pre-computed bidirectional join
- Traversal is like pointer dereferencing
 - ▶ Almost as fast as well
- Index-free Adjacency
 - ▶ Each node maintains a direct link to its adjacent nodes
 - ▶ Each node is effectively a micro-index to the adjacent nodes
- Cheaper than global indexes
 - ▶ Query are faster, do not depends on the total size of the graph



Slides 3-10 are based on Graph Database chapter 6.1 and 6.2



Neo4j Architecture



Page 163 of Graph Database

- Graph data is stored in *store files* on disk
 - ▶ Nodes, relationships, properties and labels all have their own store files.
 - ▶ Separating graph and property data promotes fast traversal
- user's view of their graph and the actual records on disk are structurally dissimilar



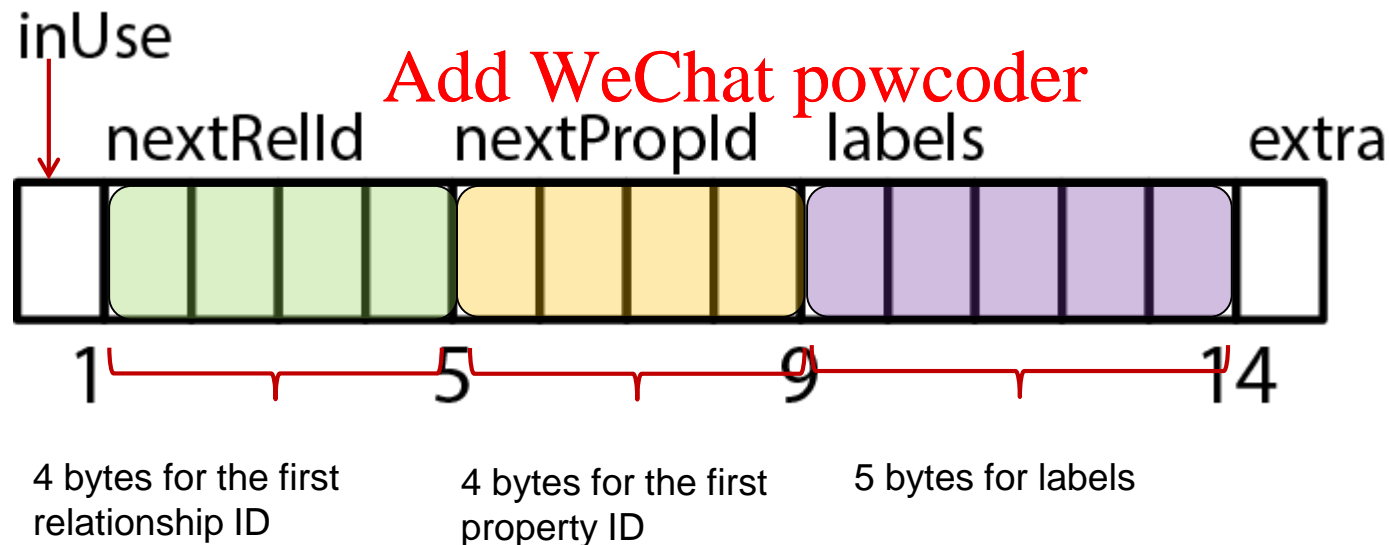
Node store file

- All node data is stored in one node store file
- Physically stored in file named *neostore.nodestore.db*
- Each record is of a **fixed size** – 15 bytes (*was 9 bytes in earlier version*)
- Offset of stored node = node id * 15 (node id = 100, offset = 1500)
- Deleted IDs in .id file and can be reused

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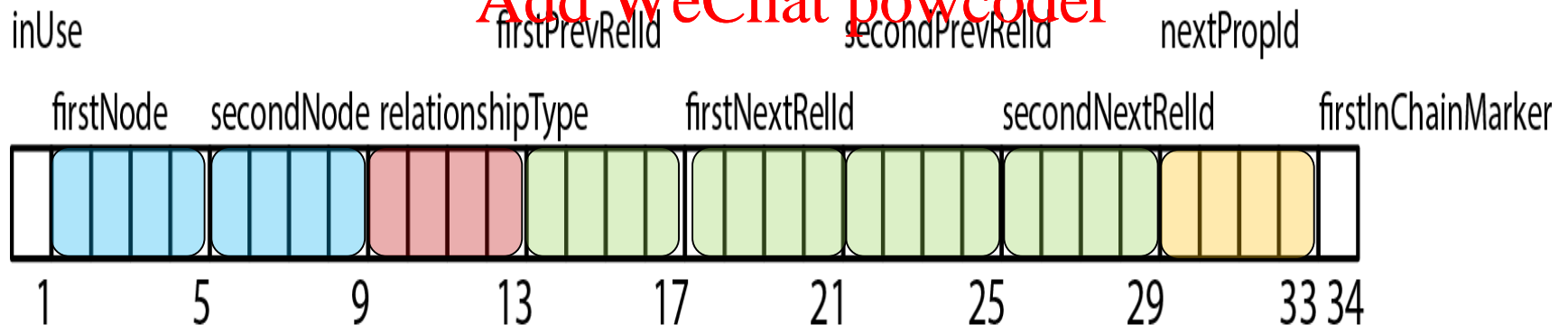
Relationship store file

- All relationship data is stored in one relationship store file
- Physically stored in file named *neostore.relationshipstore.db*
- Each record is of a fixed size – 34 bytes
- Offset of stored relationship = relationship id * 34
 - ▶ So, relationship id = 10, offset = 340

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Other Files

- **Property store** contains fixed size records to store properties for nodes and relationships
 - ▶ Simple properties are stored inline
 - ▶ Complex ones such as long string or array property are stored elsewhere
- Node label in node records references data in **label store**
- Relationship type in relationship record references data in **relationship type store**
- Both Node ID and Property ID are of 4 bytes
 - ▶ The maximum ID value is $2^{32} - 1$
 - ▶ ID is assigned and managed by the system
 - The corresponding record will be stored in the computed offset
 - ▶ The IDs of deleted nodes/relationships will be reused

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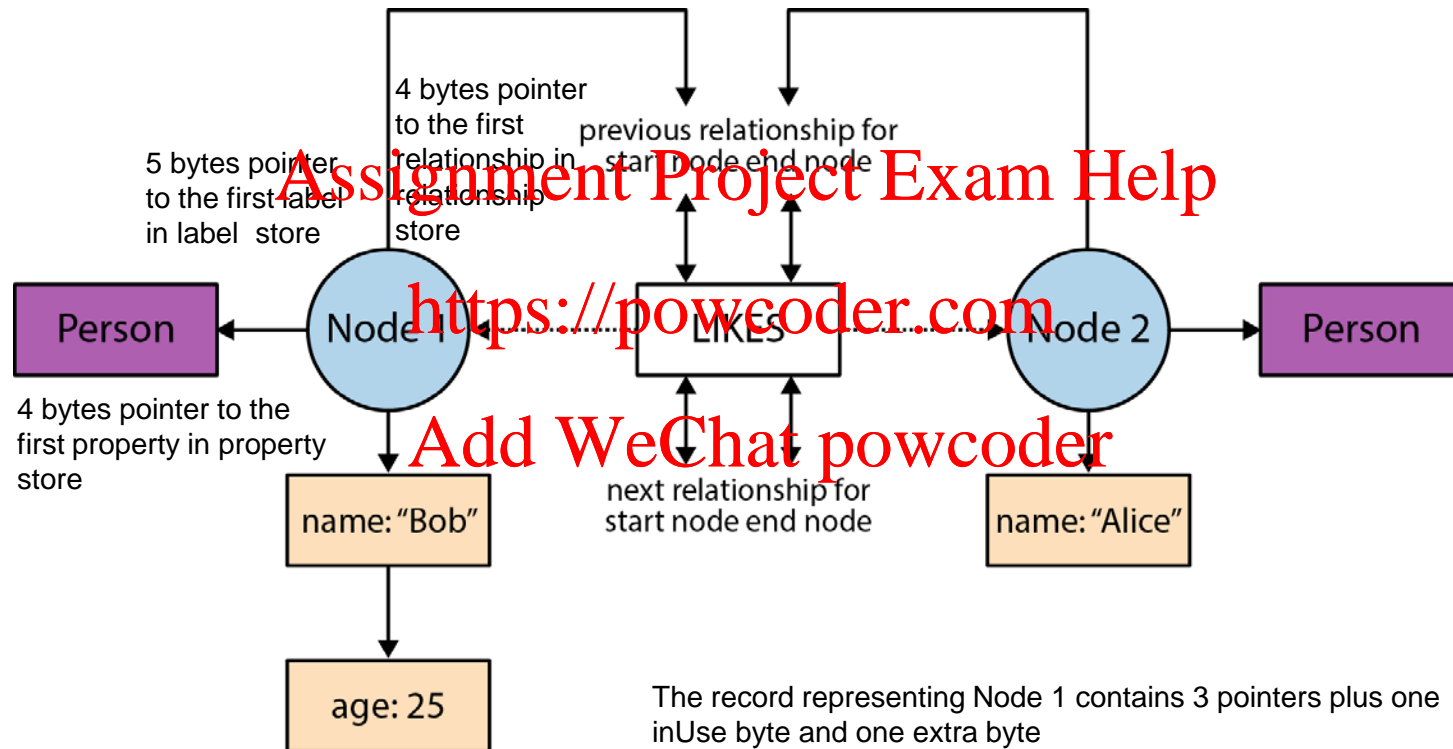
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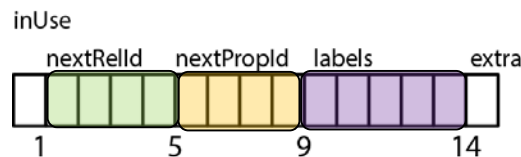


Node structure

■ Bob LIKES Alice

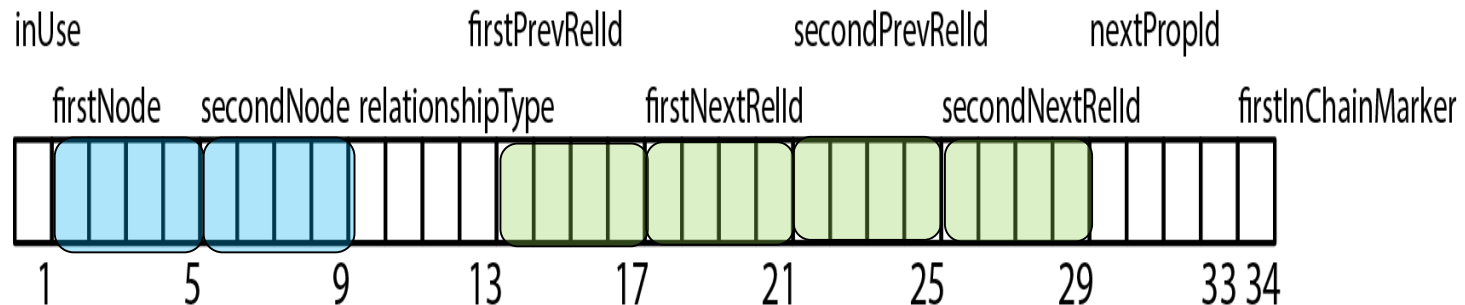
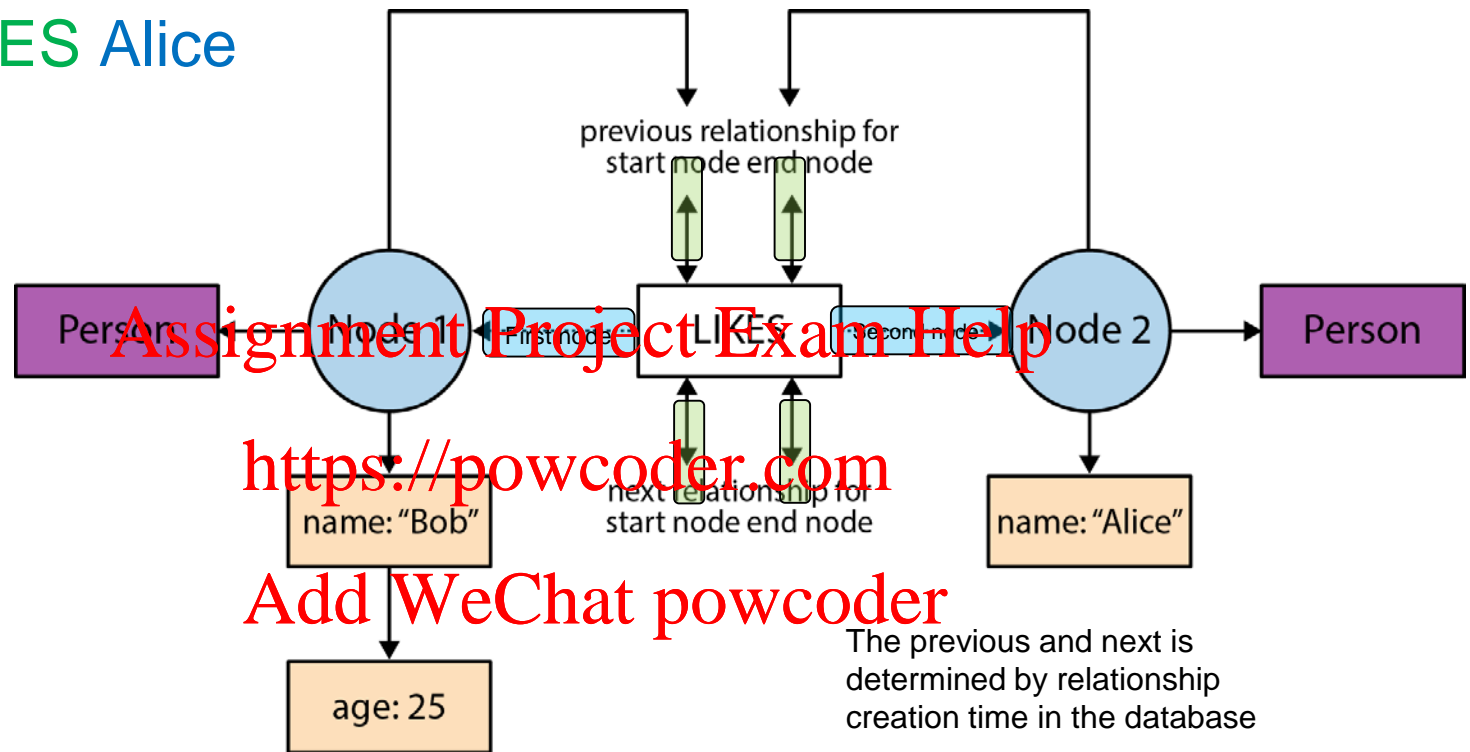


The record representing Node 1 contains 3 pointers plus one inUse byte and one extra byte

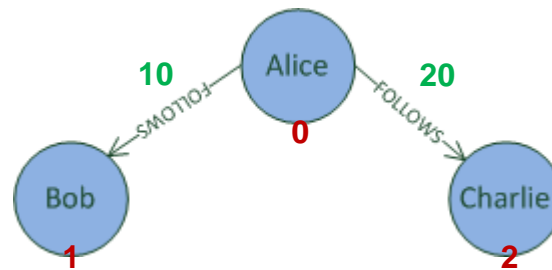


Relationship structure

■ Bob **LIKES** Alice



Doubly linked list



Creation order:

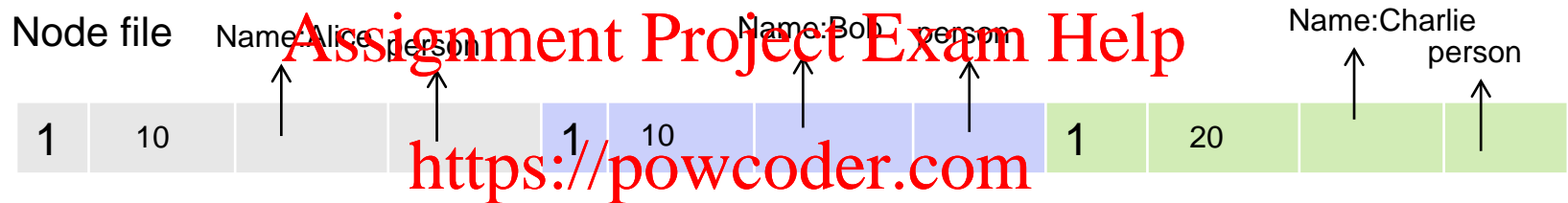
node Alice

node Bob

node Charlie

relationship Alice --> Bob

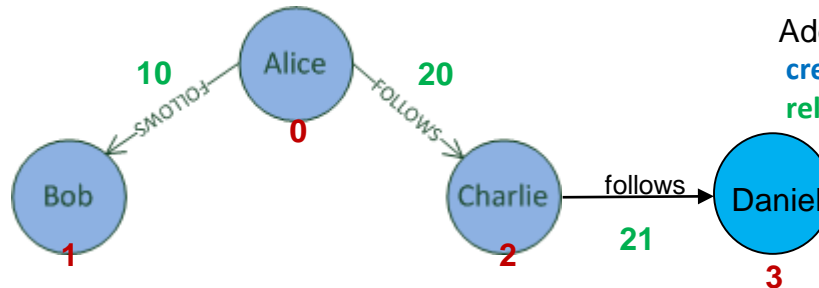
relationship Alice --> Charlie



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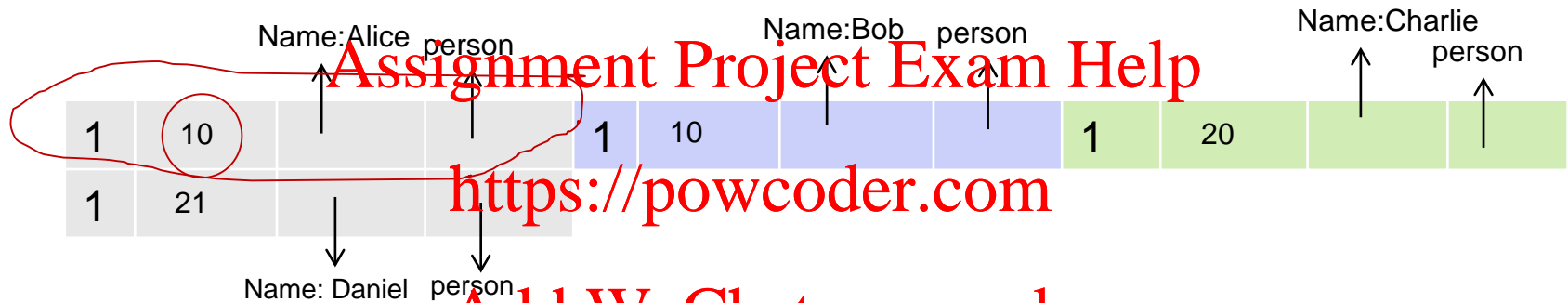


Doubly linked list (cont'd)

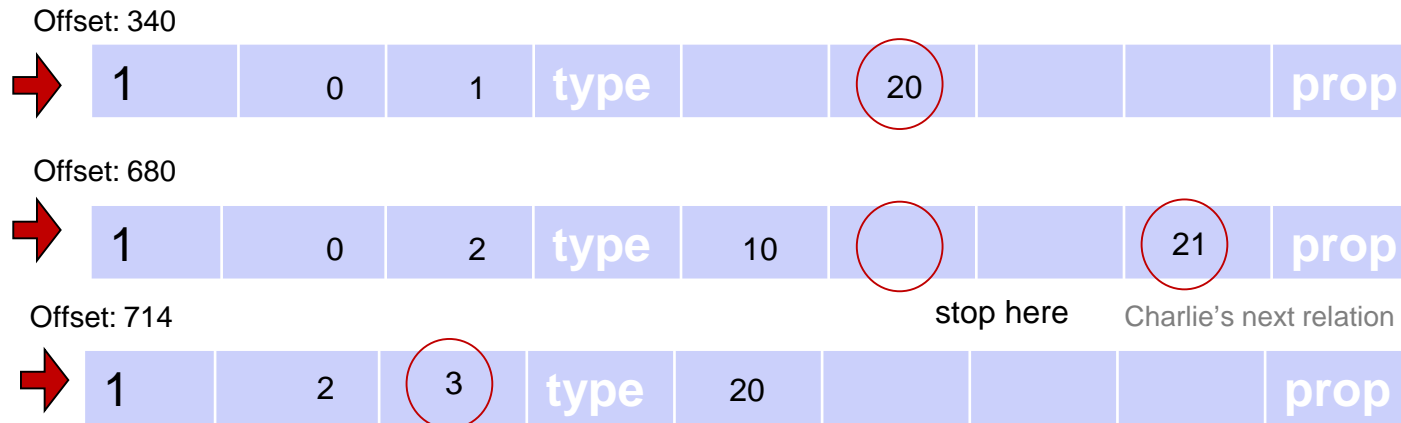


Add another node and relationship
 create node Daniel
 relationship Charlie --> Daniel

Node file



Relationship file



Charlie's previous relation

stop here

Charlie's next relation

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MATCH (Person, Name: "Alice") -[*2]->(other) RETURN other



*“The node and relationship stores are concerned **only** with the **structure** of the graph, not its property data. Both stores use fixed-sized records so that any individual record’s location within a store file can be rapidly computed given its ID. These are critical design decisions that underline Neo4j’s commitment to high-performance traversals.”*

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-- Chapter 6, Graph Databases



Outline

- Neo4j Storage

- **Neo4j Query Plan and Indexing**

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- Neo4j – Data Modeling

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- Neo4j – Graph Algorithms

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Neo4j Query Execution

- Each Neo4j Query is turned into an execution plan by a **execution planner**
 - ▶ **Rule** Strategy Planner
 - Consider available indexes but does not use statistical information
 - ▶ **Cost** Strategy Planner (default and in development)
 - Use statistic information to evaluate a few alternative plans
 - E.g. If there are less Movie nodes than People nodes, a query involving both may get better performance if starting from a collection of Movie nodes
 - See example in lab
- Query plan stages
 - ▶ Starting point
 - ▶ Expansion by matching given path in the query statement
 - ▶ Row filtering, skipping, sorting, projection, etc...
 - ▶ Combining operations
 - ▶ Updating

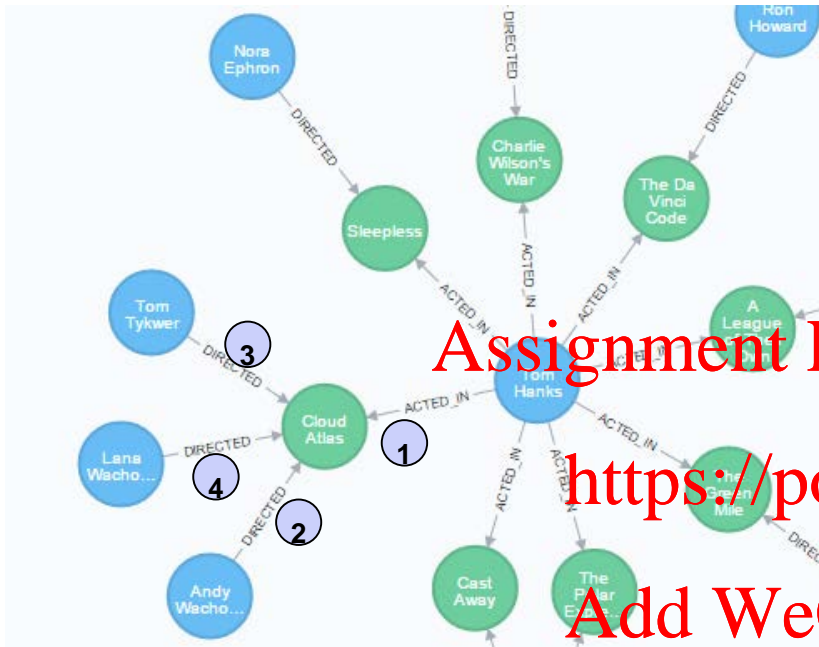
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Query Plan: an example



Query:

MATCH

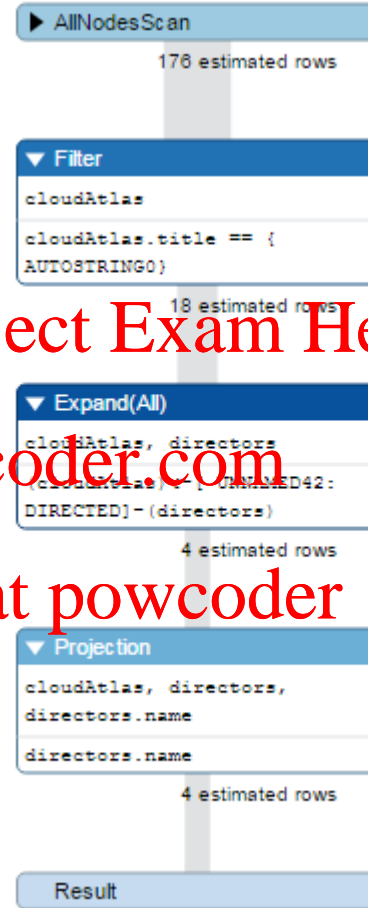
`(cloudAtlas {title: "Cloud Atlas"})<-[:DIRECTED]-(directors)`

RETURN directors.name

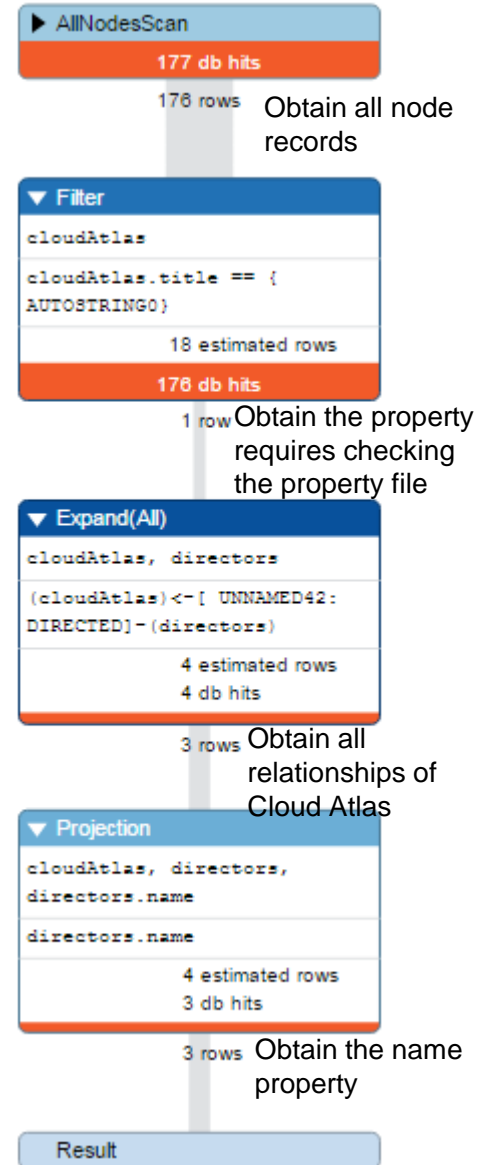
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explain



profile



Query Starting Points

- Most queries start with one or a set of **nodes** except if a relationship ID is specified
 - ▶ `MATCH (n1)-[r]->() WHERE id(r)= 0 RETURN r, n1`
 - ▶ This query will start from locating the first record in the relationship file
- Query may start by scanning all nodes
 - ▶ `MATCH(n) RETURN (n)`
 - ▶ `MATCH (cloudAtlas {title: "Cloud Atlas"})<-[:DIRECTED]-(directors) RETURN directors.name`
- Query may start by scanning all nodes belonging to a given label
 - ▶ `MATCH (p:Person{name:"Tom Hanks"}) return p`
 - ▶ Labels are implicitly indexed
- Query may start by using index

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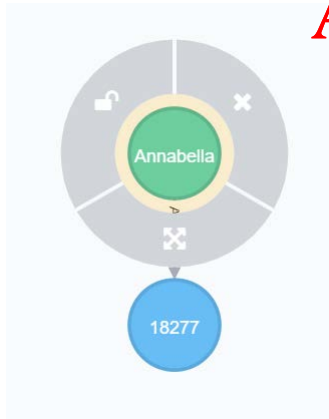
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Query starting from labelled node

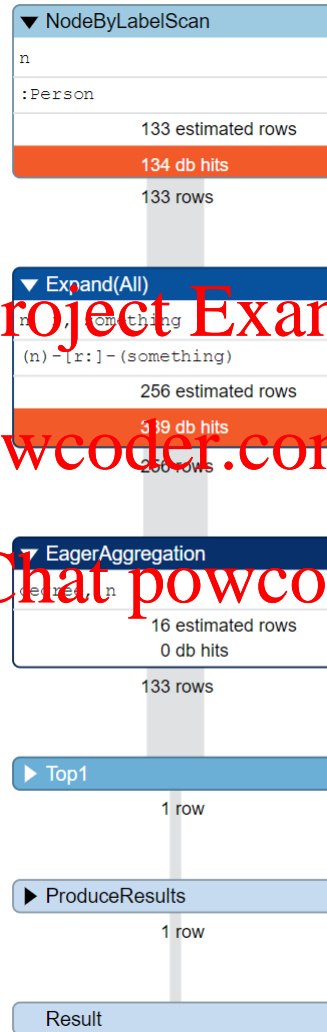
MATCH (n:Person) -[r]-(something)
with n, count(something) as degree
order by degree
limit 1
return n



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Obtain all 133
Person nodes
records

Obtain 133 nodes +
256 relationships

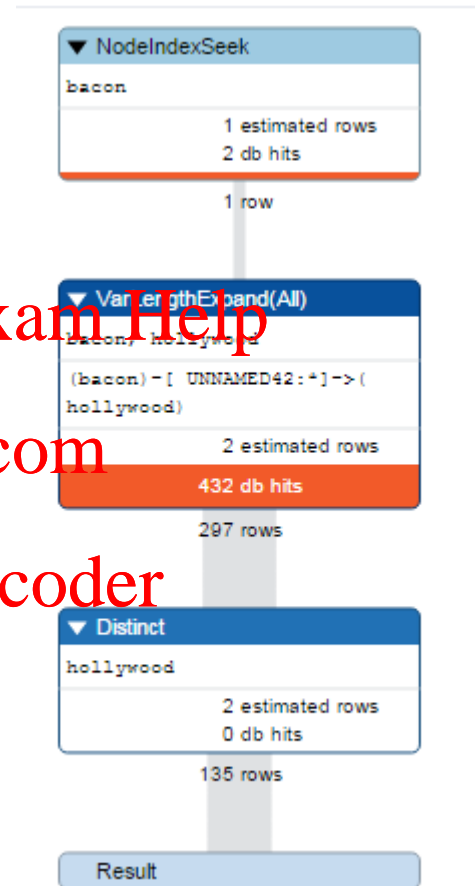
Memory processing

Query Plan With Index

- Neo4j supports index on properties of labelled node
- Index has similar behaviour as those in relational systems
- It can be built on single or composite properties
- Create Index
 - ▶ **CREATE INDEX ON :Person(name)**
- Drop Index
 - ▶ **DROP INDEX ON :Person(name)**

Query:

```
MATCH (bacon:Person {name:"Kevin Bacon"})-[*1..4]-(hollywood)
RETURN DISTINCT hollywood
```



A relatively complex query and plan

MATCH (n:Person{name: "Tom Hanks"})

WITH n.phone as phones, n

UNWIND phones as phone

MATCH (m:Person)

WHERE phone in m.phone and n<>m

RETURN m.name

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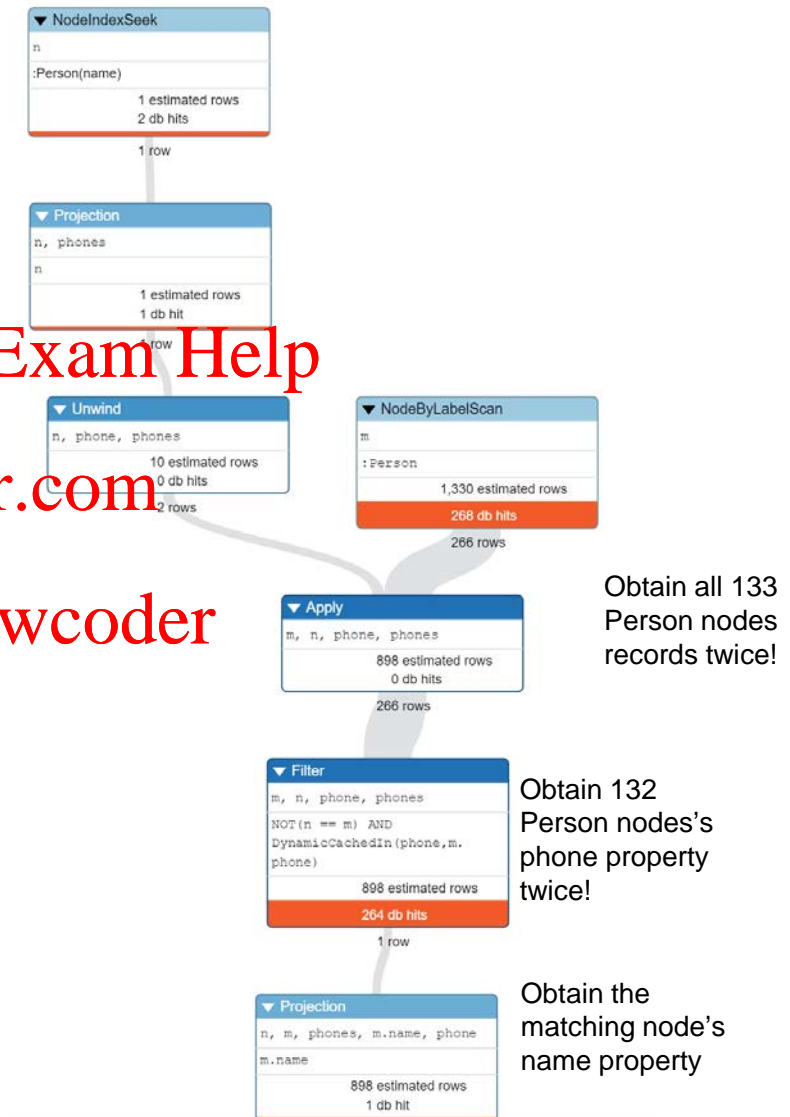
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Apply works by performing a nested loop. Every row being produced on the left-hand side of

the **Apply** operator will be fed to the leaf operator on the right-hand side, and

then **Apply** will yield the combined results

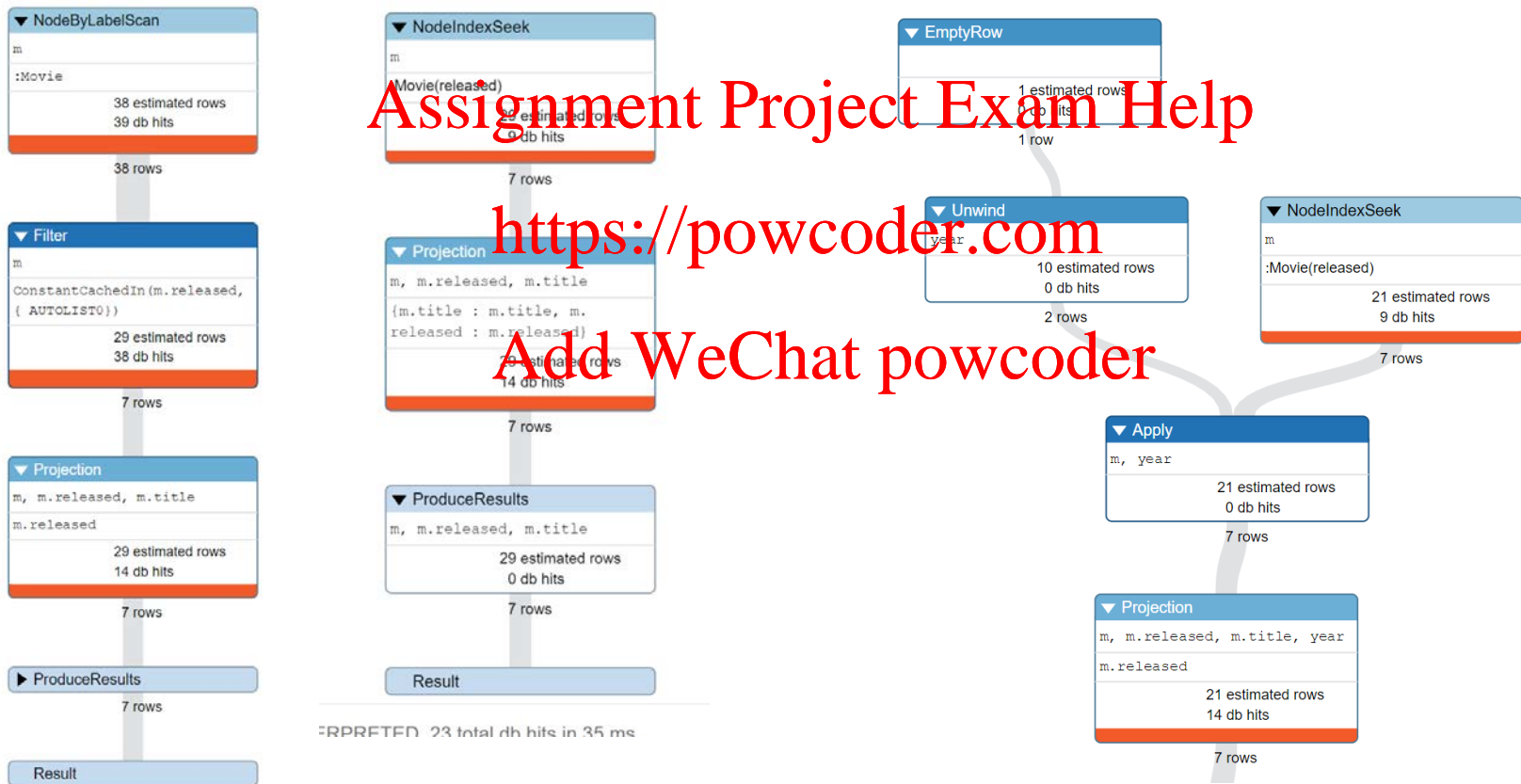
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Comparing Execution Plans

MATCH (m: Movie)
WHERE m.released IN [1999,2003]
RETURN m.title, m.released

UNWIND [1999,2003] as year
MATCH (m: Movie)
WHERE m.released = year
RETURN m.title, m.released



Earlier version

version 3.2



Another example of comparison

- Question: Find out a list of person who has acted in at least three movies and also directed at least one movie
- Cypher is powerful and flexible
 - ▶ It is possible to write very different queries that produce the same results
 - ▶ The performance could have big difference
 - ▶ The DB engine does not have much knowledge to rewrite the queries as those in SQL
 - Not based on relational algebra

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Option 1

MATCH (p:Person)-[:ACTED_IN]->(m:Movie)

WITH p, count(m) AS mc

WHERE mc > 2

MATCH (p)-[:DIRECTED]->(m2:Movie)

RETURN p.name, m2.title

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Projection	
mc, p	
mc > { AUTOINT0 }	
13 estimated rows	0 db hits

102 rows

Filter	
mc, p	
anon[74]	
3 estimated rows	0 db hits

15 rows

15 person have acted in at least 3 movies

Expand(All)	
m2, p, mc	
(p) - [UNNAMED89:DIRECTED] -> (m2)	
3 estimated rows	16 db hits

1 row

Need to check all 15 person's relationships

Filter	
m2, p, mc	
m2:Movie	
3 estimated rows	1 db hit

1 row

Check the movie node

Projection	
m2, p.name, p, mc, m2.title	
m2.title	
3 estimated rows	2 db hits

1 row

Getting two properties

NodeByLabelScan	
m	
:Movie	
38 estimated rows	39 db hits

38 rows

Expand(All)	
m, p	
(m) - [UNNAMED87:ACTED_IN] -> (p)	
172 estimated rows	210 db hits

172 rows

Filter	
m, p	
p:Person	
172 estimated rows	172 db hits

172 rows

EagerAggregation	
mc, p	
13 estimated rows	0 db hits

102 rows



Option 2

MATCH (m1:Movie)<-[a:ACTED_IN]-(p:Person)-[:DIRECTED]->(m2:Movie)

WITH p, count(distinct m1) as ac m2

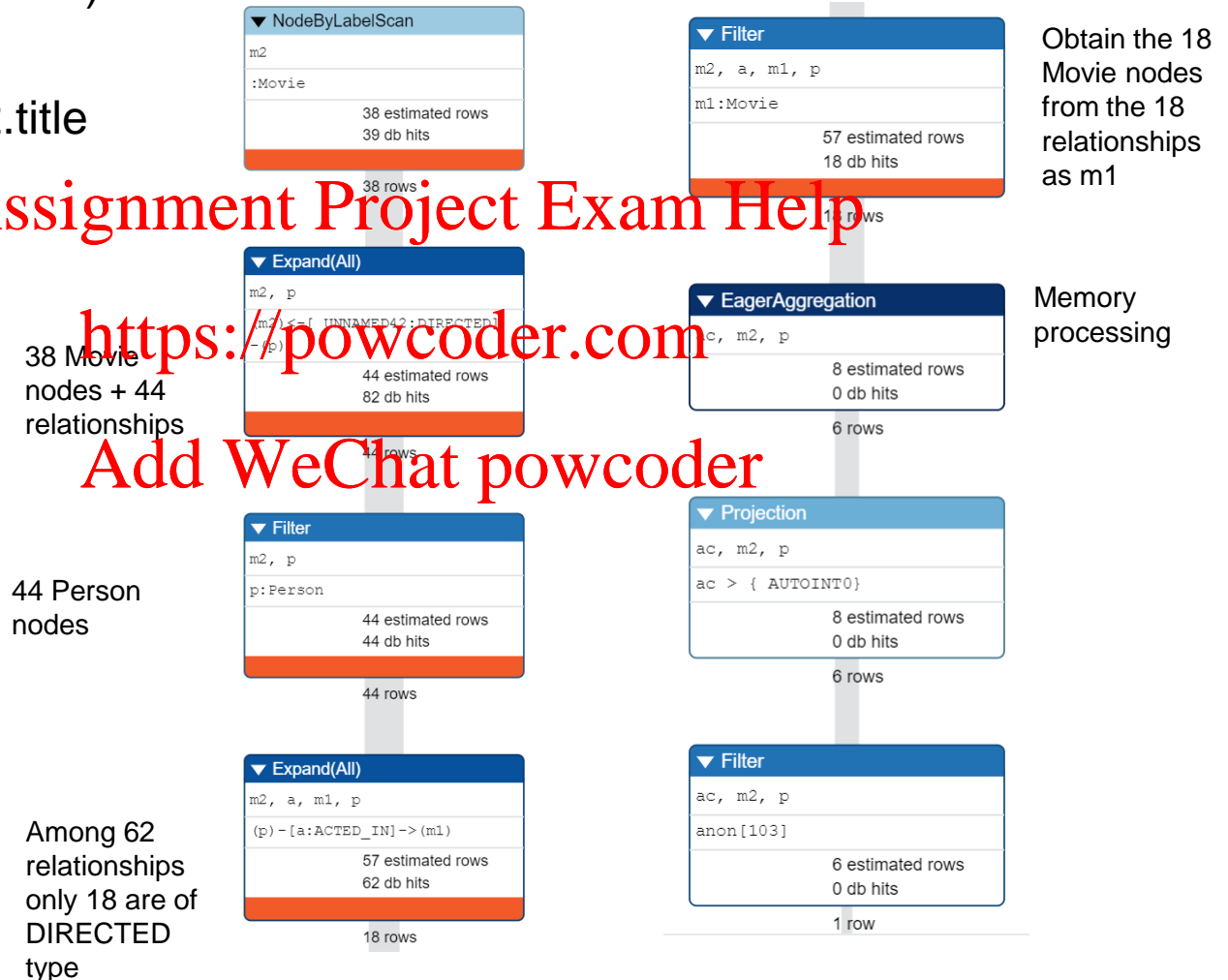
WHERE ac > 2

RETURN p.name, m2.title

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Transactions

- Neo4j supports full ACID transactions
 - ▶ Similar to those in RDBMS
- Uses locking to ensure consistency
 - ▶ Lock Manager manages locks held by a transaction
- Logging
 - ▶ Write Ahead Logging (WAL)
- Transaction Commit Protocol
 - ▶ Acquire locks (Atomicity, Consistency, Isolation)
 - ▶ Write Undo and Redo records to the WAL
 - for each node, relationship, property changed is written to the log
 - ▶ Write commit record to the log and flush to disk (Durability)
 - ▶ Release locks
- Recovery – if the database server/machine crashes
 - ▶ Apply log records to replay changes made by the transactions

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Outline

- Neo4j Storage

- Neo4j Query Plan and Indexing

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- **Neo4j – Data Modeling**

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- Neo4j – Graph Algorithms

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Graph Data Modelling

- Graph data modelling is very closely related with domain modelling
- You need to decide
 - ▶ Node or Relationship
 - ▶ Node or Property
 - ▶ Label/Type or Property
- Decisions are based on
 - ▶ Features of entities in application domain
 - ▶ Your typical queries
 - ▶ Features and constraints of the underlying storage system

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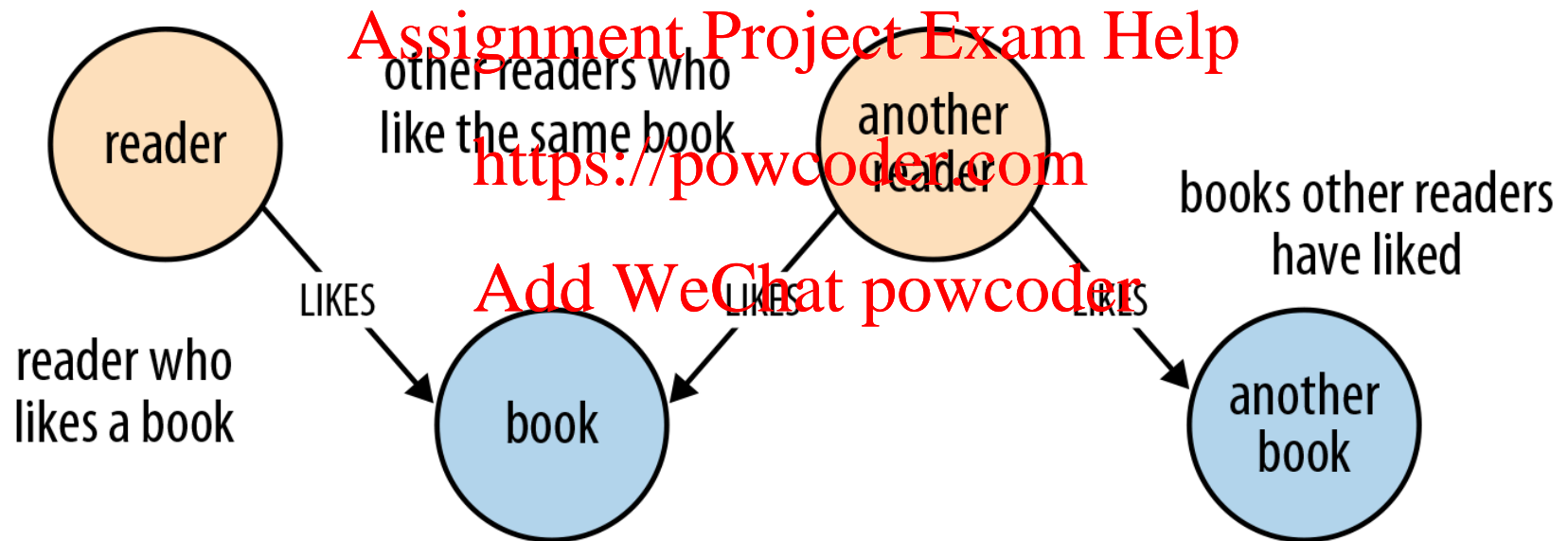
Slides 35-39 are based on Chapter 4 of Graph Databases book



Node vs. Relationship

■ Nodes for Things, Relationship for Structures

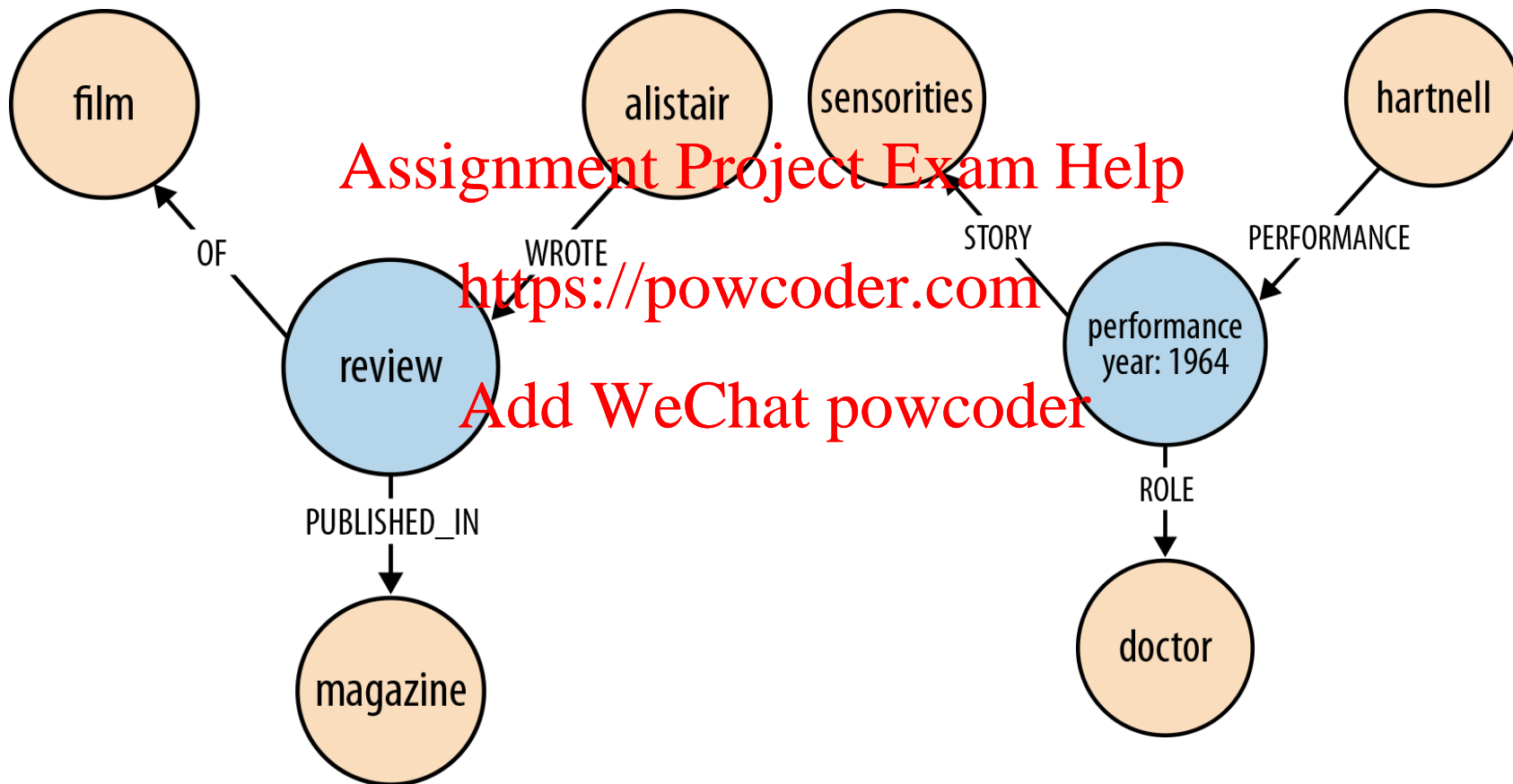
- ▶ **AS** A reader who likes a book, **I WANT** to know which books other readers who like the same book have liked, **SO THAT** I can find other books to read.



```
MATCH (:Reader {name:'Alice'})-[:LIKES]->(:Book {title:'Dune'})  
<-[:LIKES]-(:Reader)-[:LIKES]->(books:Book)  
RETURN books.title
```

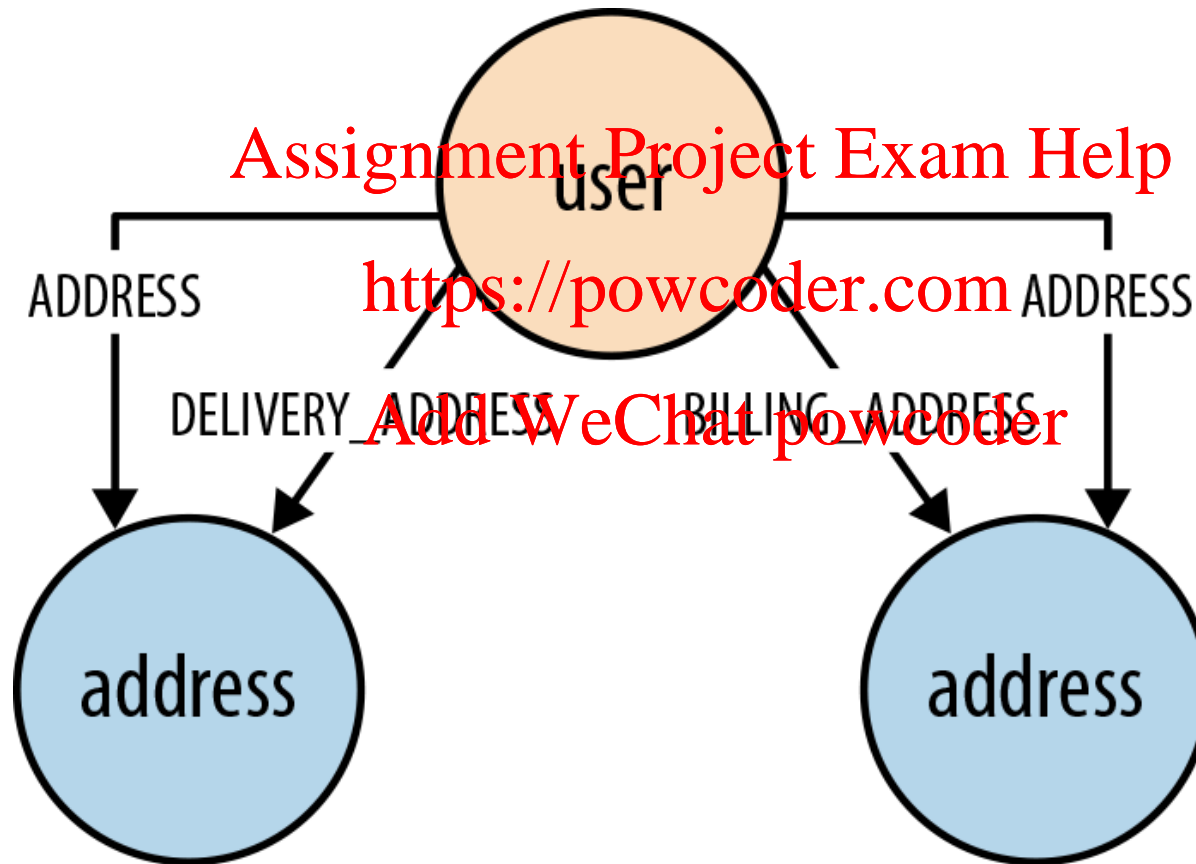
Node vs. Relationship

■ Model Facts as Nodes



Node or Property

- Represent Complex Value Types as Nodes



Relationship Property or Relationship Type

- E.g. The relationship between user node and address node can be:
 - typed as **HOME_ADDRESS**, **BILLING_ADDRESS** or
 - typed as generic **ADDRESS** and differentiated using a type property {type:'home'}, {type:'billing'}
- We use fine-grained relationships whenever we have a closed set of relationship types.
 - ▶ Eg. there are only a finite set of address types
 - ▶ If traversal would like to follow generic type **ADDRESS**, we may have to use redundant relationships
 - `MATCH (user)-[:HOME_ADDRESS|WORK_ADDRESS|DELIVERY_ADDRESS]->(address)`
 - `MATCH (user)-[:ADDRESS]->(address)`
 - `MATCH (user:User)-[r]->(address:Address)`

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- Neo4j – Data Modeling

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- **Neo4j** – Graph Algorithms

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Graph Algorithm

- In addition to graph query and traversal, a rich set of graph algorithms are provided by Neo4j
 - ▶ Used to be part of the Neo4j server
 - ▶ It is now moved out as a separate project
- The graph algorithms are implemented as Cypher **procedures** and need to be installed separately
- Procedure is a mechanism to extend Neo4j
 - ▶ Take arguments, perform database operation and return result
 - ▶ Written in Java and compiled to jar files
 - ▶ Once installed, it can be called directly from Cypher

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<https://neo4j.com/docs/graph-algorithms/3.4/>

<https://neo4j.com/docs/developer-manual/current/extending-neo4j/procedures/>



References

- Ian Robinson, Jim Webber and Emil Eifrem, *Graph Databases*, Second Edition, O'Reilly Media Inc.,

- ▶ You can download this book from the Neo4j site,
<https://neo4j.com/graph-databases-book/?ref=home>
 - Chapter 4, Chapter 6

- Neo4j – Reference Manual <https://powcoder.com>

- ▶ <https://neo4j.com/docs/developer-manual/current/>
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