RDF in the Database: Enabling Semantically Rich Business Applications

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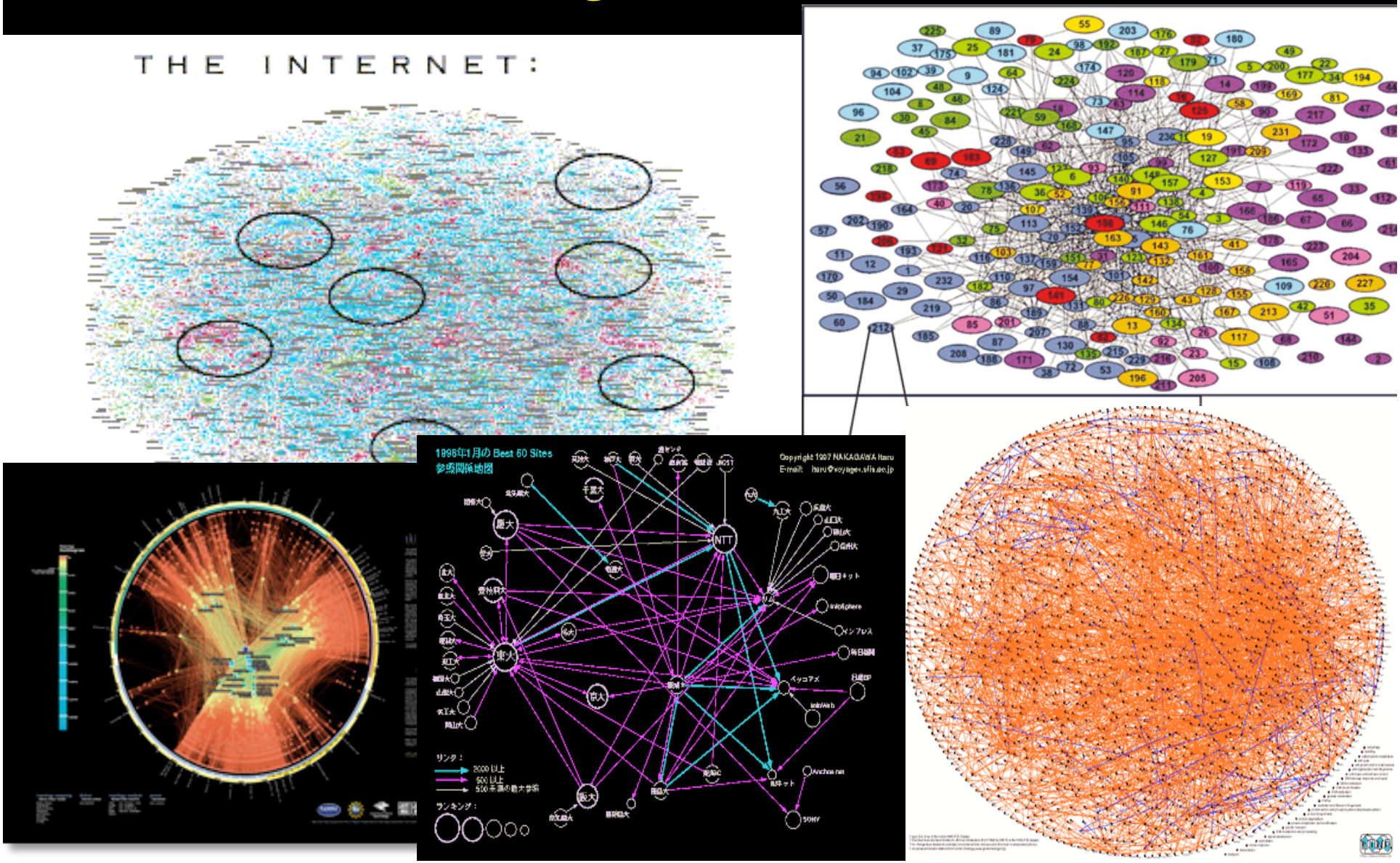
Overview

- Semantic Applications Opportunity
- Semantic Technology Primer - RDF
- Germane Oracle10g Database Technologies
  - Network Data Model
  - RDF
  - OWL

Networks to Model Systems

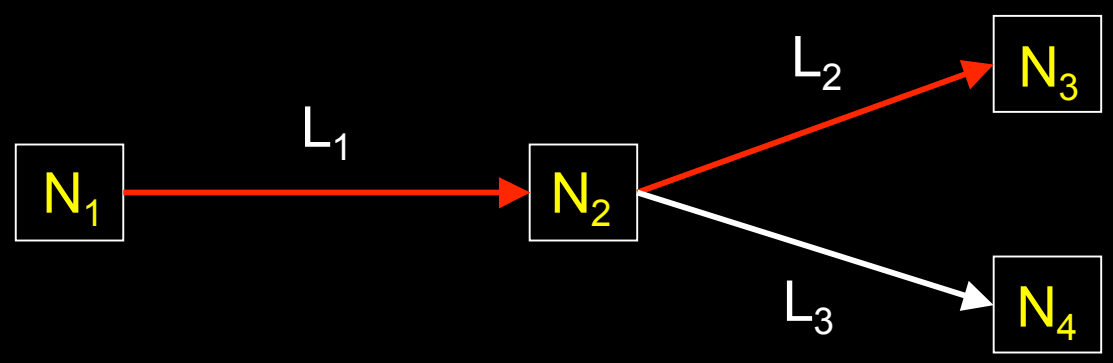
Life Sciences, Ontologies, Social Networks



Network Concepts:

A network is a graph representation for modeling objects of interest and their relationships. It contains the following elements:

- Nodes: objects of interests (e.g. intersection, subject)
- Links: relationship between nodes (e.g. street, property)
- Paths: ordered list of connected links (e.g. scenic route, interaction)



- RDF introduces a universal way to manage graph representation

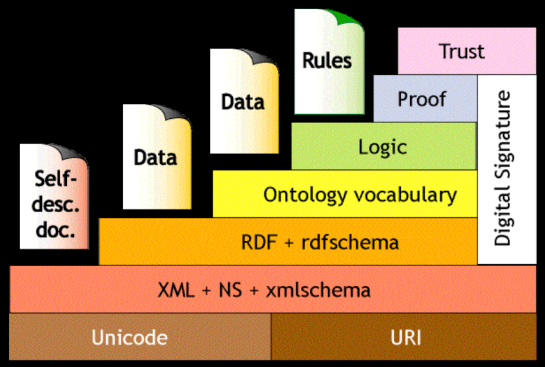
RDF Data Model Opportunities

- Unique Business Opportunities
  - Life Sciences: pathway analysis, protein interaction
  - Web: service discovery, FOAFs, blogs
  - eBusiness: grid resources, app integration, BI
  - Security: social networks, provence, varying trust
- Applying DBMS Technology to the Challenge
  - Scalability: models comprising millions of graphs
  - Security: Web-based, trust, reification
  - Transaction, versioning, performance
  - Exploit expressive power of SQL
  - Interoperability: Integrating multiple networks

Semantic Technologies

- Goal: Associating more meaning (context) to enterprise data to enable its use across applications
  - Common framework to express information to be exchanged between applications without loss of meaning
- How? Develop technologies to allow sharing and reuse of enterprise and web data.

W3C Stack of languages



- **XML**:
  - Surface syntax, no semantics
- **XML Schema**:
  - Describes structure of XML documents
- **RDF**:
  - Graph data model for “relations” between “things”
- **RDF-Schema**
  - Defines a domain vocabulary for RDF
- **OWL**:
  - A more expressive Vocabulary Definition Language

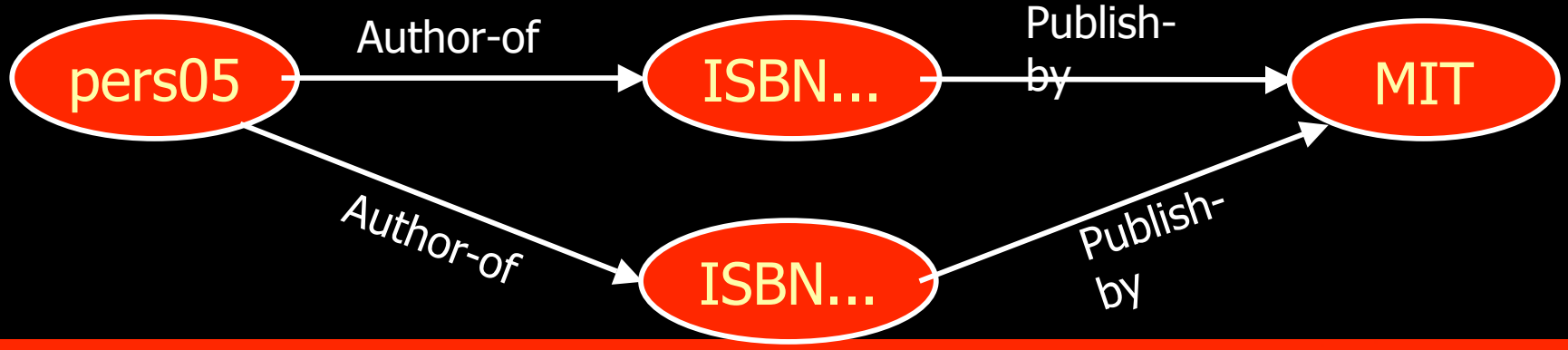
Resource Description Framework (RDF)

- **Originally conceived as W3C's metadata model**
  - Document metadata for digital libraries, content rating, site maps, etc.
- **Simple data model**
  - Leverages syntactic extensibility and modularity of XML namespaces
  - Provides global extensibility through a common data model
  - Directed labeled graph: "subject/property/object"
  - Nodes are called "resources" and links "properties"

RDF Statements (1)

- RDF specifies simple descriptions of resources
- Subject ->Property-> Object triples

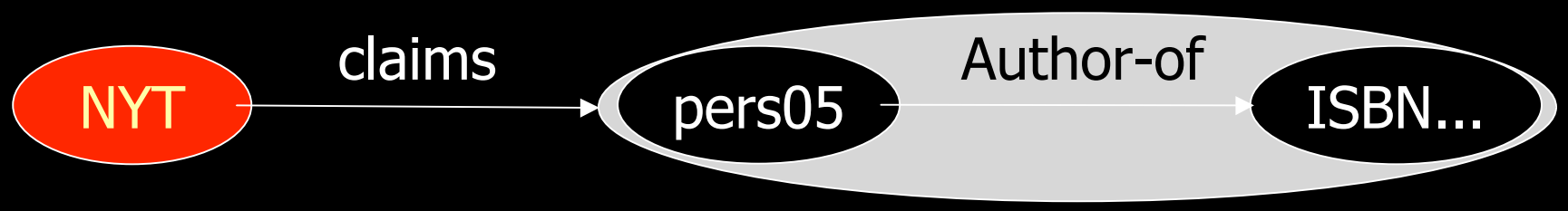
- Objects are web-resources (URIs)
- Subject is again an Object:
  - triples can be **linked**



RDF Statements (2)

- Every identifier is a URI
  = world-wide unique naming!

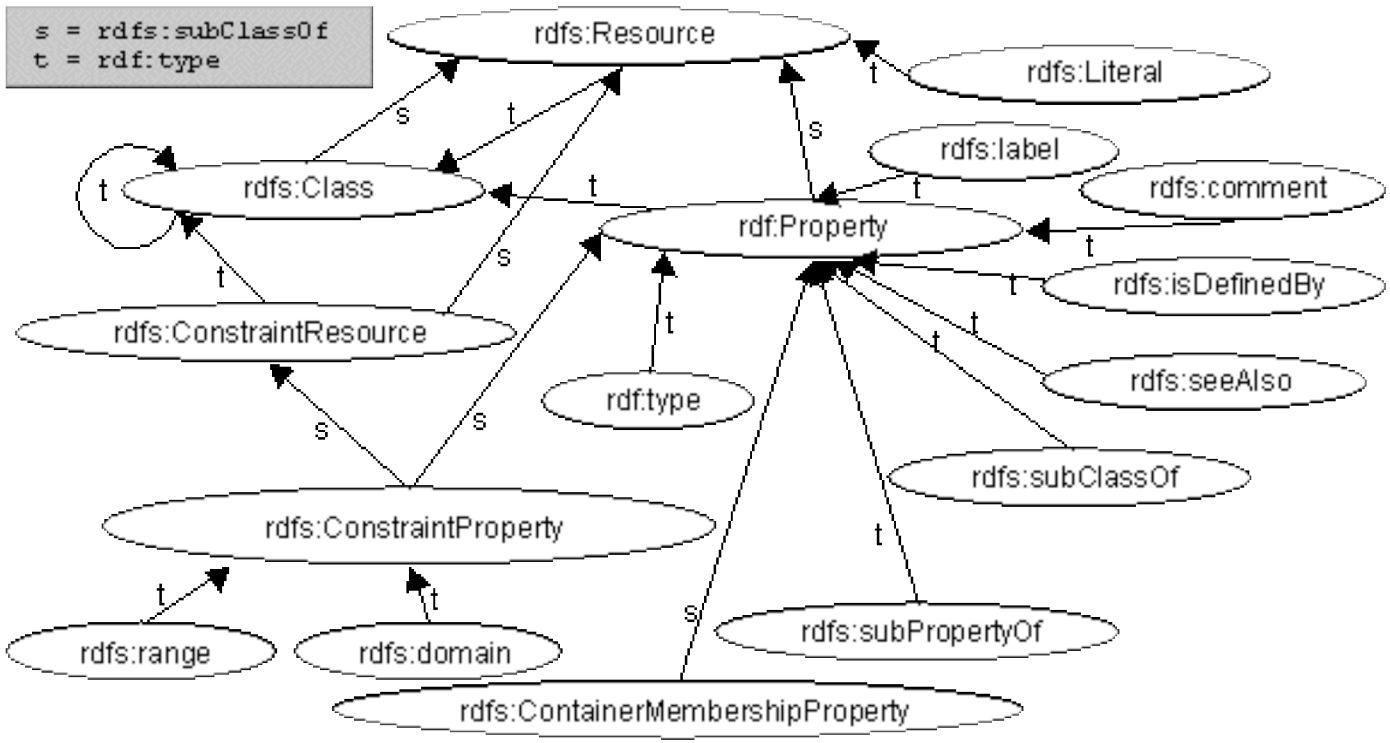
- Any statement can be a resource
  - represented by a node
  - graphs can be nested
  - Reification example:
    - Metadata: author, date, source.



RDF Schema (RDFS)

- Allows creation of class and property hierarchies
  - Ex: <`NCI:Rheumatoid_Arthritis`
    `rdfs:subClassOf`
    `NCI:Autoimmune_Disease‘>
  - Defines a domain vocabulary for RDF
  - Organises this vocabulary into a typed hierarchy
- RDF Schemas have URIs and can be described using RDF

RDFS Data Model



RDF Inferencing

- Employing symmetry and transitivity characteristics of properties to infer new relationships
- RDF Statements + RDFS rules
- Syntax for specifying user-defined rules
  - Enabled by RDFS

Beyond RDF: OWL
Web Ontology Language

- OWL builds on RDF and RDF Schema for describing sophisticated relationships for inclusion in (domain-specific) Ontologies
- Incorporates Ontologies being developed by various industry domains
  - Life Sciences
  - National Security
  - Health Care
  - Manufacturing

Oracle10g Network Data Model

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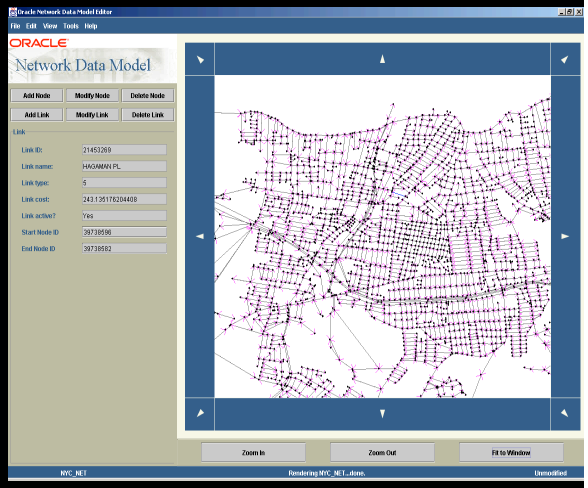
Oracle Spatial NDM

- Provide an open and generic network data model and analysis platform for graph-based applications (store, index, query)
- Combine specialized application information with a general network data
- Applies efficient network algorithms and constraints to support graph analysis
- Enable 3rd party tools and apps

NDM Analytical Capabilities

- Canonical network analysis functions
  - Shortest path between two nodes
  - All paths between two nodes
  - Nodes reachable from a given node
  - All nodes within cost *c* from a given node
  - Nodes capable of reaching a given node
  - Nearest *n* nodes from a given node
  - Minimum Cost Spanning Tree
  - Traveling Salesman Problem
- Framework to apply network constraints
  - (path length, cost, links to avoid, etc.)



Perform Shortest Path Analysis in 10g

Oracle Network Data Model Editor

File Edit View Analysis Help

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Network Data Model

Mouse

Mouse x:	-73.96156929013465
Mouse y:	40.75507176157079

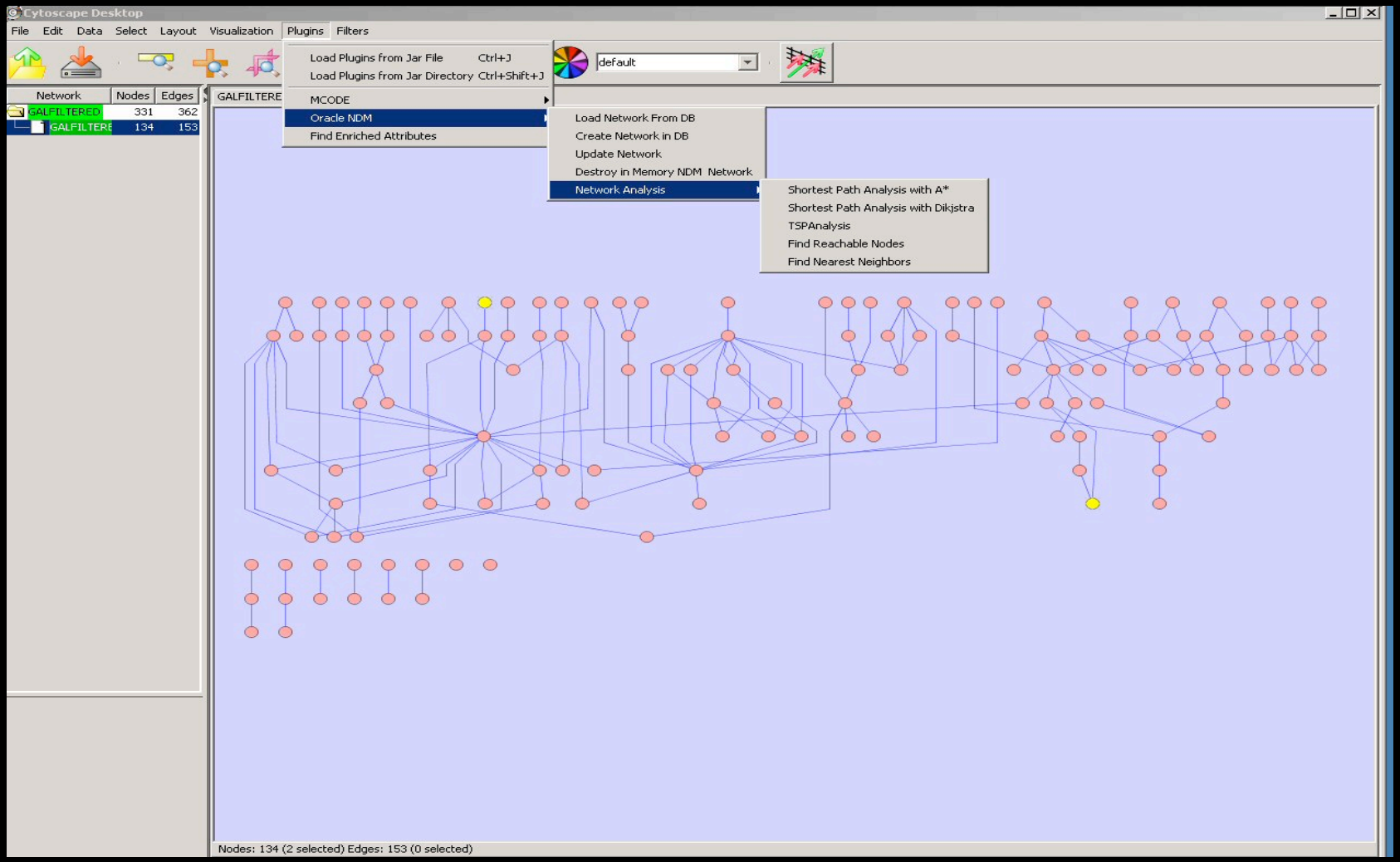
Shortest Path Result

Compute time:	110 ms
Start Node ID:	39804422
End Node ID:	39800184
Algorithm name:	A* Search
Path Cost:	3345.616749073347
Shortest Path:	CLICK TO SHOW PATH

Zoom In | Zoom Out | Fit to Window

NYC_NET | Rendering NYC_NET...done. | Unmodified

Shortest Path Analysis: KEGG Data



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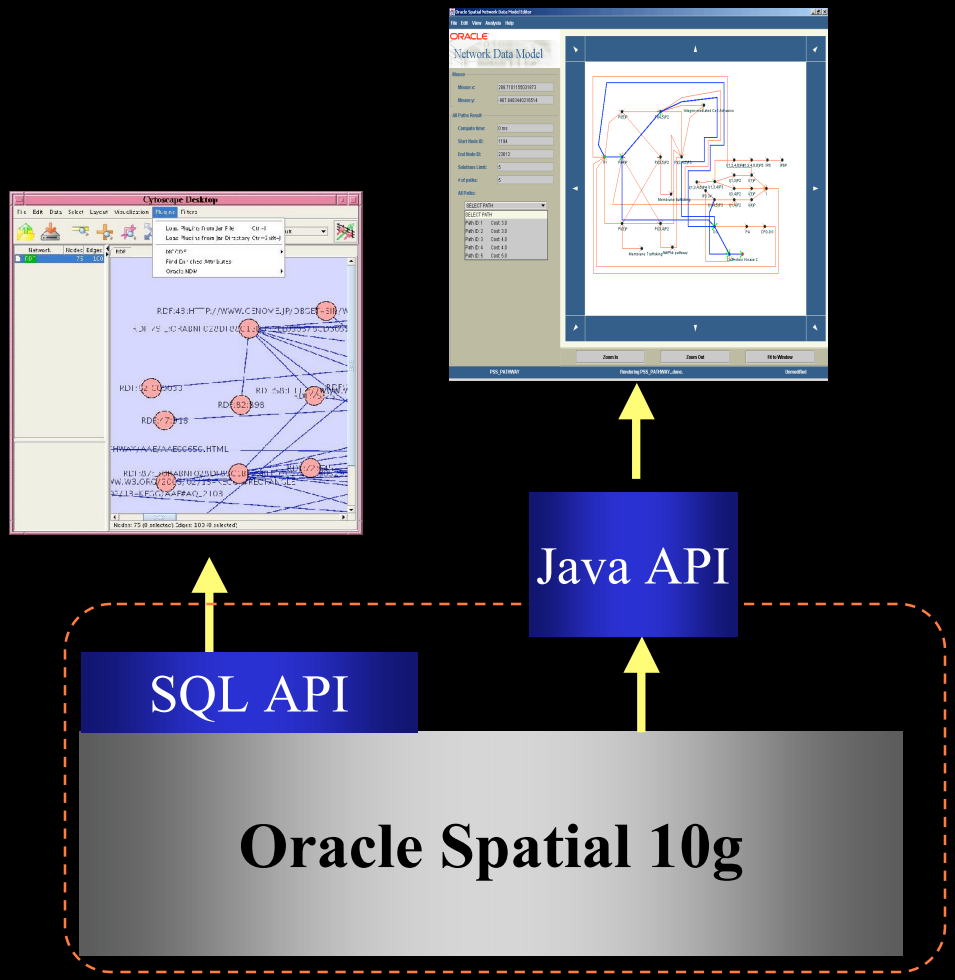
NDM Architecture



Thick or Thin Client
Browsing, navigation, presentation, editing, and analysis

Java API:
Network features loaded as in-memory Java objects in client tier or middle tier

Network Schema:
Persistent node, link, path and path-link tables along with metadata

RDF Support in Oracle10g R2

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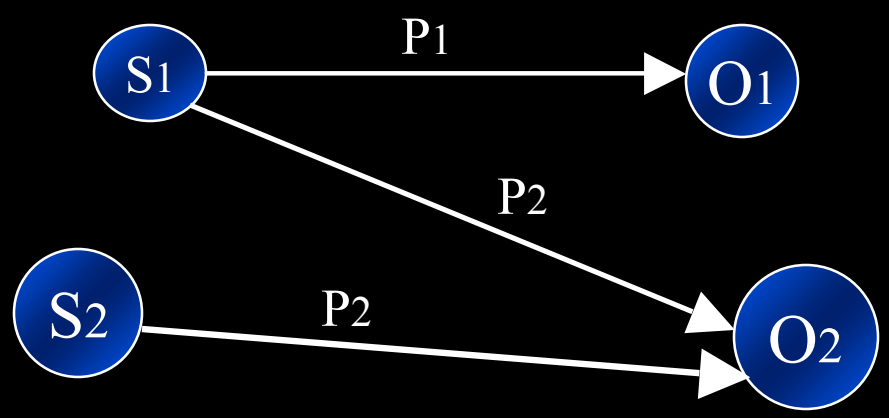
RDF Design Objectives:

- ☒ Extend NDM to support RDF object types
- ☒ Enable RDF with graph analysis
- ☒ Enable combined SQL query of enterprise database and RDF graphs
- ☒ Support large, complex graphs (10s of millions statements)
- ☒ Easily extensible by 3rd party tools/apps

RDF in Oracle Spatial

- RDF data stored in a directed, logical network
- Subjects and objects mapped to nodes, and properties to links that have subject start nodes and object end nodes
- Links represent complete RDF triples.



RDF Triples:

- {S1, P1, O1}
- {S1, P2, O2}
- {S2, P2, O2}

RDF Object Type in 10g R2

- Two new RDF object types
  - SDO_RDF_TRIPLE
  - SDO_RDF_TRIPLE_S
- Several constructors and member functions
- RDF Data Types (URIs, Blank Nodes, Plain, Typed and Long Litterals, Collections Types)
- Multiple representations of values
- Reification

RDF Querying: Overview

- Extend SQL using Extensibility Framework
  - RDF_MATCH table function
  - for graph pattern specification in query
- SPARQL –like syntax (W3C) support
- SQL-level access to RDF data
- Java API

RDF Querying: Example

- Find pairs of persons residing at the same address such that first person rents a truck and the second person buys fertilizer

```
SELECT t3.x name1, t3.y name2
FROM AddrTable t1, AddrTable t2,
TABLE(RDF_MATCH(RDFModels('transactions'), …
  '(?x :rents ?a) (?a rdf:type :truck)
   (?y :buys  ?b) (?b rdf:type :fertilizer)'
…)) t3
WHERE t1.name=t3.x and t2.name=t3.y and
      t1.addr=t2.addr;
```

- Shows embedding of a RDF query in a SQL query

RDF Querying: Example

- Find pairs of persons residing at the same address such that first person rents a truck and the second person buys fertilizer

```
SELECT t3.x name1, t3.y name2
FROM AddrTable t1, AddrTable t2,
TABLE(RDF_MATCH(
 '(?x :rents ?a) (?a rdf:type :truck)
  (?y :buys  ?b) (?b rdf:type :fertilizer)',
 RDFModels('activities','vehicles','chemicals'),
 RDFRulebases('rdfs')
 …)) t3
WHERE t1.name=t3.x and t2.name=t3.y and
      t1.addr=t2.addr;
```

- Shows embedding of a graph query in a SQL query

Use Cases:

- Astra Zeneca – Biological Pathways Analysis
- Beyond Genomics – Pathways Analysis
- GlaxoSmithKlein – Pathways Analysis
- Kyoto Univ. (KEGG) – Pathways Analysis
- Nature Publishing – Citation Analysis
- Overstock.com – Customer Care
- Siderean – Enterprise Search Partner
- Tom Sawyer – Graph Visualization Tool
- Cytoscape – Graph Visualization Tool

Planned OWL Support

Oracle's Approach:

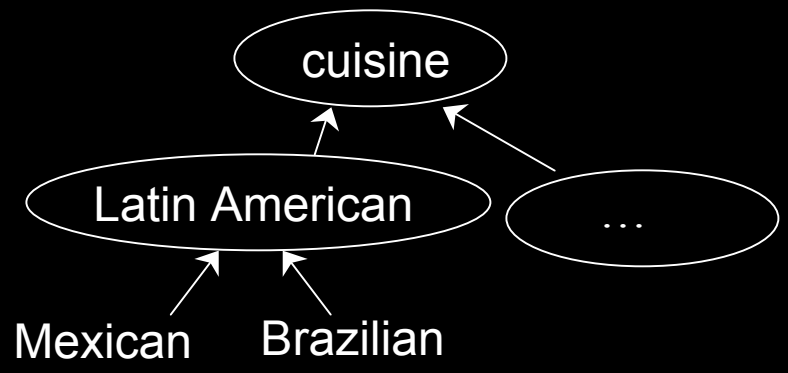
- ☒ Allow OWL Ontologies to be stored in a set of Oracle tables
- ☒ Provide a collection of SQL Operators and SQL Table Functions to query OWL Ontologies

Restaurant Example

served_food

R_id	Cuisine
1	American
2	Mexican
2	American
14	Brazilian

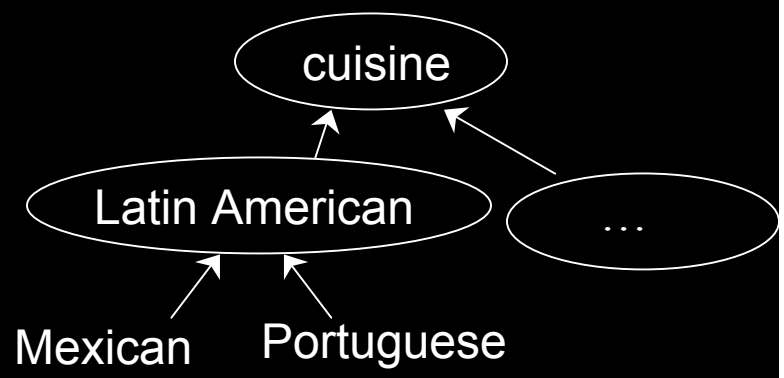
Cuisine_ontology



Querying Cuisine Ontology

```
SELECT * FROM served_food
WHERE ONT_RELATED ( cuisine,
                    'IS_A',
                    'Latin American',
                   'Cuisine_ontology')=1;
```

Cuisine_ontology



Result:

R_id	Cuisine
2	Mexican
14	Brazilian

Additional Ontology Queries

- Semantic filtering
- Query with path length constraints
- Query with path content constraints
- Semantic join

Status

- Design & Implementation
  - RDF Querying → 10gR2 database
  - OWL Querying → prototyped, planned for 11x database

QUESTIONS & ANSWERS

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