

Rapidly Integrating Services into the Linked Data Cloud

Mohsen Taheriyani, Craig Knoblock,
Pedro Szekely, Jose Luis Ambite

About: Downtown Los Angeles [Sponge](#) [Permalink](#)

An Entity of Type : [Neighborhoods in Los Angeles, California](#), within Data Space

Type:

Downtown Los Angeles is the central business district of Los Angeles, the center of the metropolitan area. The area features many of the city's best shopping opportunities, a variety of skyscrapers and associated large museums and shopping opportunities. Downtown is the hub of the city's freeway system.

<u>leader title</u>	City Council U.S. House State Senate State Assembly
<u>population total</u>	39537(xsd:integer)
<u>area total (km2)</u>	8.538 13.73988692533248

Current temperature	73°F
Wind	10 mph SW
Humidity	51%
Dew Point	54°

Live weather

The Weather Channel

Los Angel... 73°F Los Angel... 70°F +

Weather Lifestyle Social Maps Video News TV

Local National Forecast Severe Weather Alerts Hurricane Central

Los Angeles Weather ☆

Local Pollen Alert

Right Now Updated: May 23, 2012, 3:45pm PDT

73°F Sunny
Feels like 73°F

From **10** mph WIND
9.0 mi VISIBILITY

51% HUMIDITY
29.74 in → PRESSURE

54° DEW POINT ⓘ
5 - Moderate UV INDEX

About: Downtown Los Angeles [Sponge](#) [Permalink](#)
 An Entity of Type : [Neighborhoods in Los Angeles, California](#), within Data Space : [dbpedia.org](#)

Type: `yago:NeighborhoodsInLosAngeles,California`

Downtown Los Angeles is the central business district and the center of the metropolitan area. The area features many shopping opportunities, a variety of skyscrapers and associated shopping opportunities. Downtown is the hub of the city.

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Events Theater	Transparent Cities 5/1/2012 REDCAT
Conversations	Saving Our Sons : A Community

Events for May. 2012

◀ ▶

Film
Transparent Cities
 5/1/2012
 REDCAT Theater

Meeting
Saving Our Sons: A Community Conversation
 5/2/2012
 Los Angeles Trade Tech College

Special Event
Autumn Lights Night
 5/3/2012
 401 s Main Street

Concert
Martin Hasselbock Leads LACO's Baroque Conversations
 5/3/2012
 Colburn School of Performing Arts

Ongoing Events

Exhibit
A Nation Emerges: The Mexican Revolution Revealed
 9/8/2011 - 6/3/2012
 LA Public Library - Central

Museum
Justice, Balance and Achievement: African Americans in the California Courts
 1/12/2012 - 5/27/2012
 California African American Museum

Exhibit
Trouble In Paradise: Music and Los Angeles, 1945-1975
 2/22/2012 - 6/3/2012
 GRAMMY Museum

Exhibit
Xploration Lab 2012
 3/17/2012 - 6/17/2012

Events

About: Downtown Los Angeles [Sponge](#) [Permalink](#)

An Entity of Type : [Neighborhoods in Los Angeles, California](#), within Data Space : [dbpedia.org](#)

Type:

Downtown Los Angeles is the central business district of Los Angeles, the center of the metropolitan area. The area features many of the city's best shopping opportunities, a variety of skyscrapers and associated large multi-story shopping opportunities. Downtown is the hub of the city's freeway system.

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Events	Transparent Cities 5/1/2012 RED Saving Our Sons : A Community ...
--------	---

Twitter Feed	Los Angeles becomes the largest U.S. city to ban.. Plastic grocery bags will now be banned in
--------------	---

Yale Environment 360 @YaleE360 18m
Los Angeles becomes the largest U.S. city to ban **plastic bags**
bit.ly/JA0PdX #LosAngeles #plasticbagban
[Expand](#)

DestinationTampaBay @DestTampaBay 48m
Plastic grocery bags will now be banned in #LosAngeles. What do you think of that concept for #Florida?
[Expand](#)

annmarie anderson @AnnmarieCloud 55m
"@HuffingtonPost: The nation's second largest city has just banned **plastic bags** in grocery stores huff.to/Jygs5N" #LosAngeles #green
[Expand](#)

gomaam @gomaam 1h
#LosAngeles is now the largest U.S. city to #ban #plastic bags
dlvr.it/1cX0bW
[Expand](#)

Ozzyopolis @Ozzyopolis 3h
Los Angeles Becomes Largest U.S. City to Ban **Plastic Bags**:
bit.ly/Jpl9xw via @TreeHugger #LosAngeles #plasticbagban
[Expand](#) [Reply](#) [Retweet](#) [Favorite](#)



Live Twitter Feed

The information is available in Web APIs

About: Downtown Los Angeles

An Entity of Type : [Neighborhoods in Los Angeles, California](#)

Type: `yago:NeighborhoodsInLosAngeles,California`

Downtown Los Angeles is the central business district of Los Angeles, California, United States, located close to the geographic center of the metropolitan area. The area features many of the city's major arts institutions and sports facilities, sightseeing opportunities, a variety of skyscrapers and associated large multinational corporations and an array of public art and unique shopping opportunities. Downtown is the hub of the city's freeway network and growing Metro rapid transit system.

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Twitter Feed	Los Angeles becomes the largest U.S. ci... Plastic grocery bags will now be banned... ...

World Weather Online API

Summary | Mashups (1) | How-To (1) | Developers (1) | Comments

World Weather Online provides weather forecast and we... for worldwide city and towns. The Developer Weather AP... developers and programmers to access free 5 day weath...

Eventful API

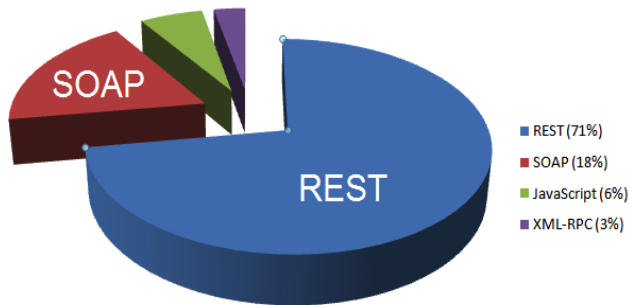
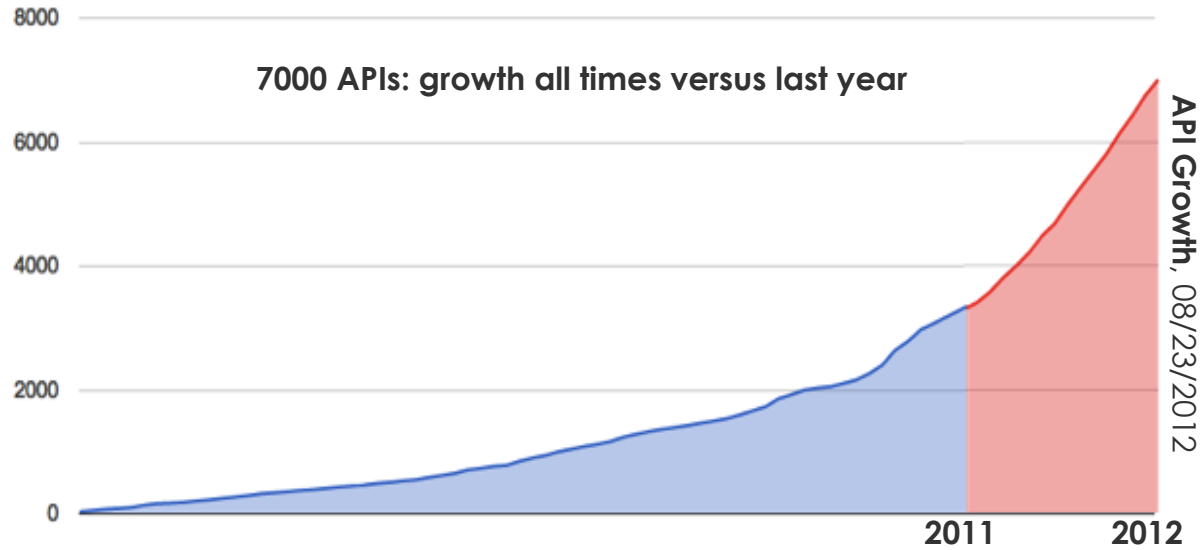
Summary | Mashups (46) | How-To | Developers (30) | Comments

Eventful is the world's largest collection of events, taking... markets throughout the world, from concerts and sports... events and political rallies. Eventful.com is built upon a...

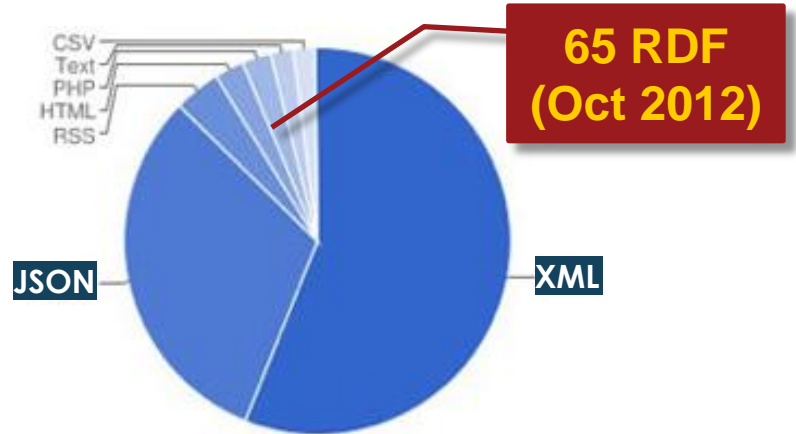
Twitter API

Summary | Mashups (709) | How-To (34) | Developers (432) | AP

The Twitter micro-blogging service includes two RE... Twitter REST API methods allow developers to acc...

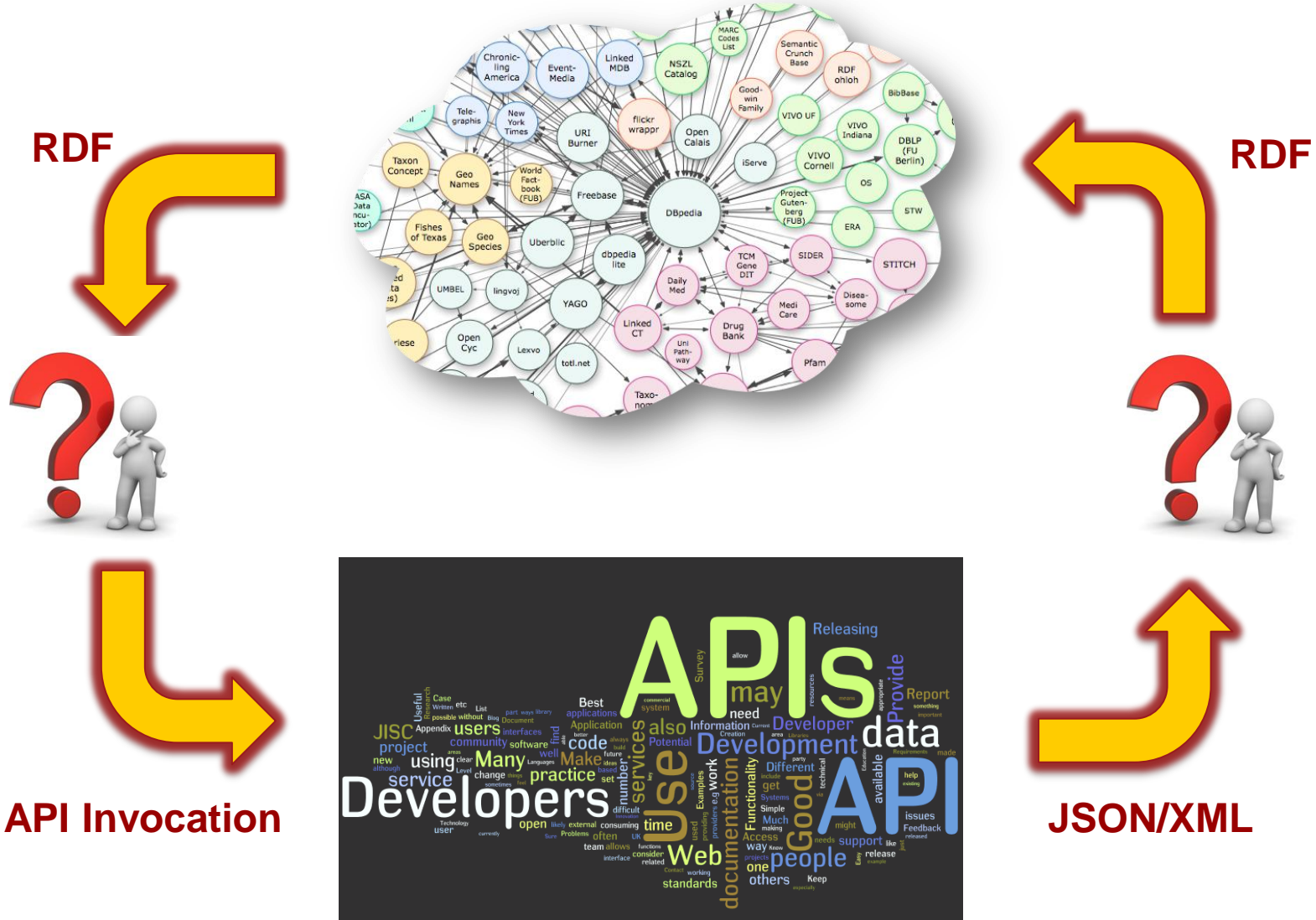


API Protocols, 02/10/2012



API Data Formats, 03/08/2011

The Problem



For most of the Web APIs, only a textual description is available

neighbourhood?

RDF Input

```
<http://sws.geonames.org/5145067/>  
  a gn:Feature ;  
  wgs84:lat "40.78343" ;  
  wgs84:long "-73.96625" .
```

Neighbourhood / reverse geocoding

The neighbourhood for US cities. Data provided by [Zillow](#) under cc-

Webservice Type : REST

Url : [api.geonames.org/neighbourhood?](#)

Parameters : lat,lng

Result : returns the neighbourhood for the given latitude/longitude

Example [http://api.geonames.org/neighbourhood?
lat=40.78343&lng=-73.96625&username=demo](http://api.geonames.org/neighbourhood?lat=40.78343&lng=-73.96625&username=demo)

Invocation Example

For most of the Web APIs, only a textual description is available

Most of the Web APIs do not consume or produce linked data (RDF)

RDF Input

```
<http://sws.geonames.org/5145067/>  
  a gn:Feature ;  
  wgs84:lat "40.78343" ;  
  wgs84:long "-73.96625" .
```

```
<http://sws.geonames.org/5145067/>  
  gn:neighbour [  
    a gn:Feature ; gn:name "Woodside";  
    gn:nearby [  
      a gn:Feature ; gn:name "...-Queens";  
      gn:parentCountry [ ...
```

Linked RDF



Lowering



Lifting

Neighbourhood / reverse geocoding

The neighbourhood for US cities. Data provided by [Zillow](#) under c

Webservice Type : REST

Url : api.geonames.org/neighbourhood

Parameters : lat,lng

Result : returns the neighbourhood for the given latitude/longitude

Example <http://api.geonames.org/neighbourhood?lat=40.78343&lng=-73.96625&username=demo>

Invocation Example

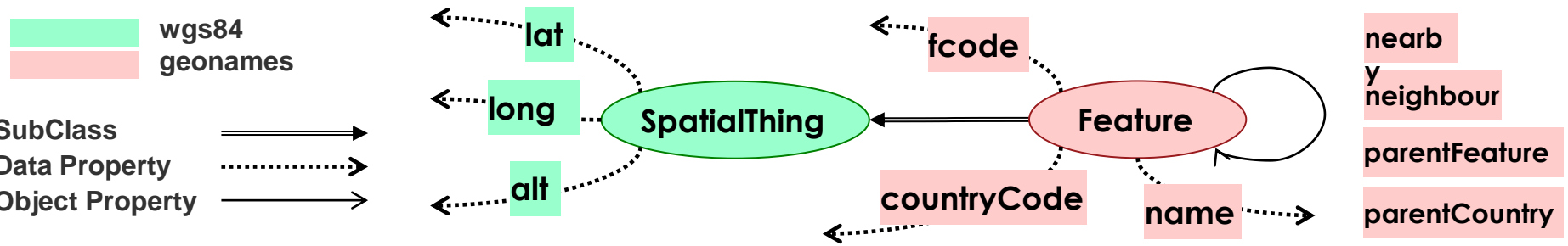
```
<geonames>  
  <neighbourhood>  
    <countryCode>US</countryCode>  
    <countryName>United States</countryName>  
    <adminCode1>NY</adminCode1>  
    <adminName1>New York</adminName1>  
    <adminCode2>061</adminCode2>  
    <adminName2>New York County</adminName2>  
    <city>New York City-Manhattan</city>  
    <name>Central Park</name>  
  </neighbourhood>  
</geonames>
```

XML Response

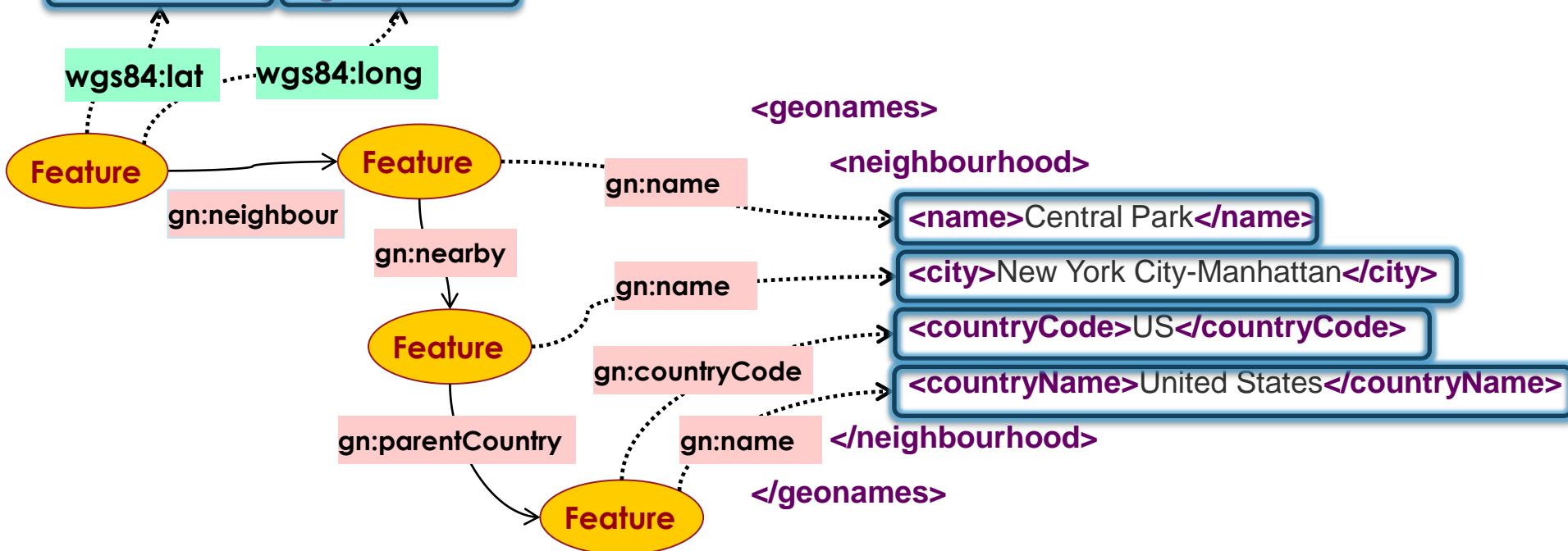
- Rapidly Integrating APIs with the LD
 - Building API Semantic Model
 - Representing API Descriptions
 - Building Linked APIs
- Evaluation
- Related Work
- Conclusion & Future Work

- Rapidly Integrating APIs with the LD
 - **Building API Semantic Model**
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The Semantic Model



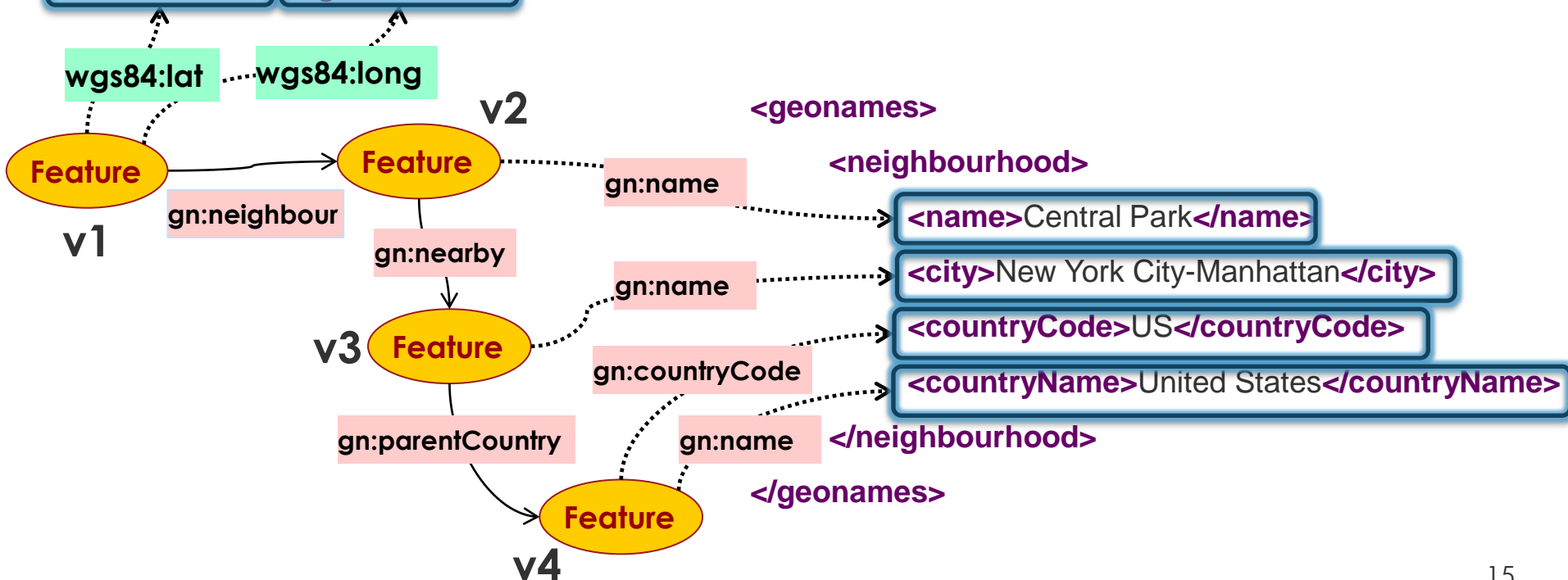
[http://api.geonames.org/neighbourhood?](http://api.geonames.org/neighbourhood?lat=40.78343&lng=-73.96625&username=demo)
lat=40.78343 lng=-73.96625 &username=demo



The Semantic Model

$\text{neighbourhood}(\$lat, \$long, @countryCode, @countryName, @city, @name) \rightarrow$
 $\text{gn:Feature}(v1) \wedge \text{wgs84:lat}(v1, \$lat) \wedge \text{wgs84:long}(v1, \$long) \wedge \text{gn:neighbourhood}(v1, v2) \wedge$
 $\text{gn:Feature}(v2) \wedge \text{gn:name}(v2, @name) \wedge \text{gn:nearby}(v2, v3) \wedge$
 $\text{gn:Feature}(v3) \wedge \text{gn:name}(v3, @city) \wedge \text{gn:parentCountry}(v3, v4) \wedge$
 $\text{gn:Feature}(v4) \wedge \text{gn:countryCode}(v4, @countryCode) \wedge \text{gn:name}(v4, @countryName)$

[http://api.geonames.org/neighbourhood?
lat=40.78343&lng=-73.96625&username=demo](http://api.geonames.org/neighbourhood?lat=40.78343&lng=-73.96625&username=demo)





Examples of
API Request
URLs

Domain
Ontology

**Karma
Modeling**



Invoking
APIs

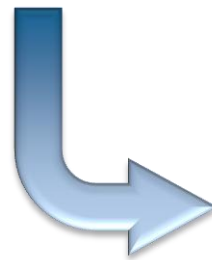
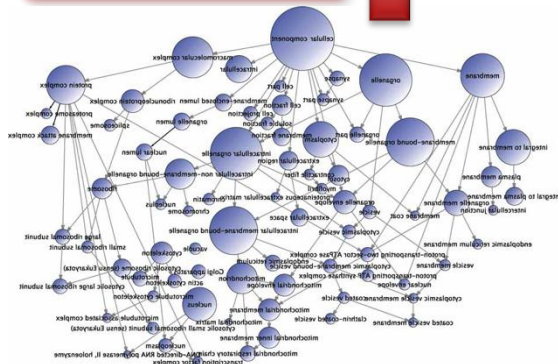


Annotating
Attributes



Extracting
Relationships

Previous
Work on
Modeling
Static
Sources



**API
Semantic
Model**

Invoking APIs

- User provides examples of the API request URLs
- Karma extracts the input values from the sample request URLs
- Karma invokes the API and extracts the output attributes from the API response (XML/JSON)

Examples of API
Invocation URLs

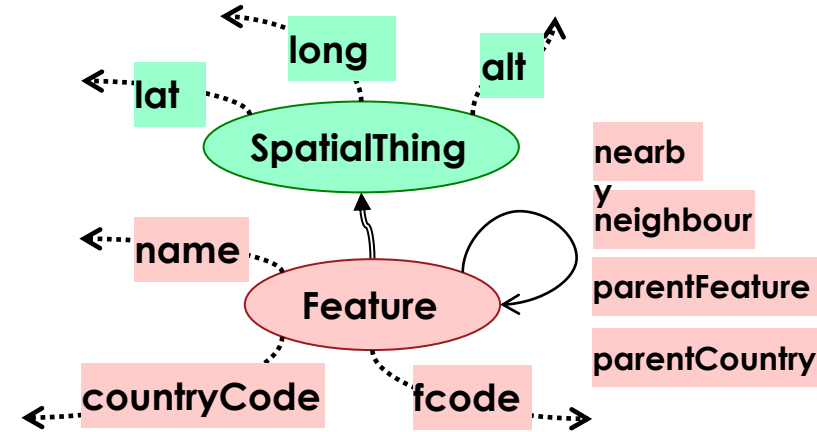
Input Attributes

Output Attributes

request url	lat	lng	username	countryCode	countryName	city	name
http://api.geonames.org/neighbourhood?lat=40.78343&lng=-73.96625&username=karma	40.78343	-73.96625	karma	US	United States	New York City-Manhattan	Central Park
http://api.geonames.org/neighbourhood?lat=40.71012&lng=-73.90078&username=karma	40.71012	-73.90078	karma	US	United States	New York City-Queens	Ridgewood
http://api.geonames.org/neighbourhood?lat=40.90145&lng=-73.90815&username=karma	40.90145	-73.90815	karma	US	United States	New York City-Bronx	Riverdale

Show: 10 20 50 records Previous Next

- A CRF-based model to assign a **Semantic Type** to each column from its data
- Semantic Type
 - Ontology Class
 - Data Property + Domain



(wgs84:lat, gn:Feature)

lat	lng	username	countryCode	countryName	city	name
40.78343	-73.96625	karma	US	United States	New York City-Manhattan	Central Park
40.71012	-73.90078	karma	US	United States	New York City-Queens	Ridgewood

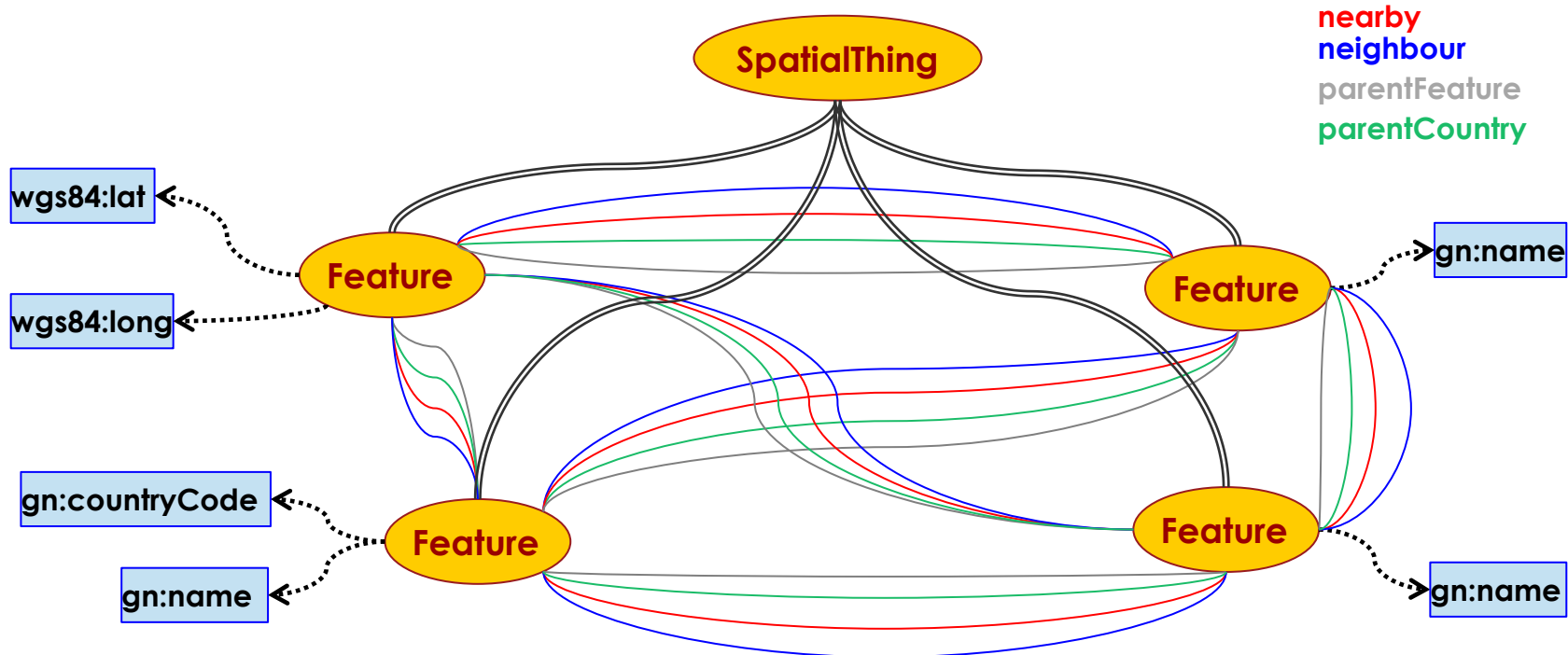
(wgs84:long, gn:Feature)

(gn:name, gn:Feature)

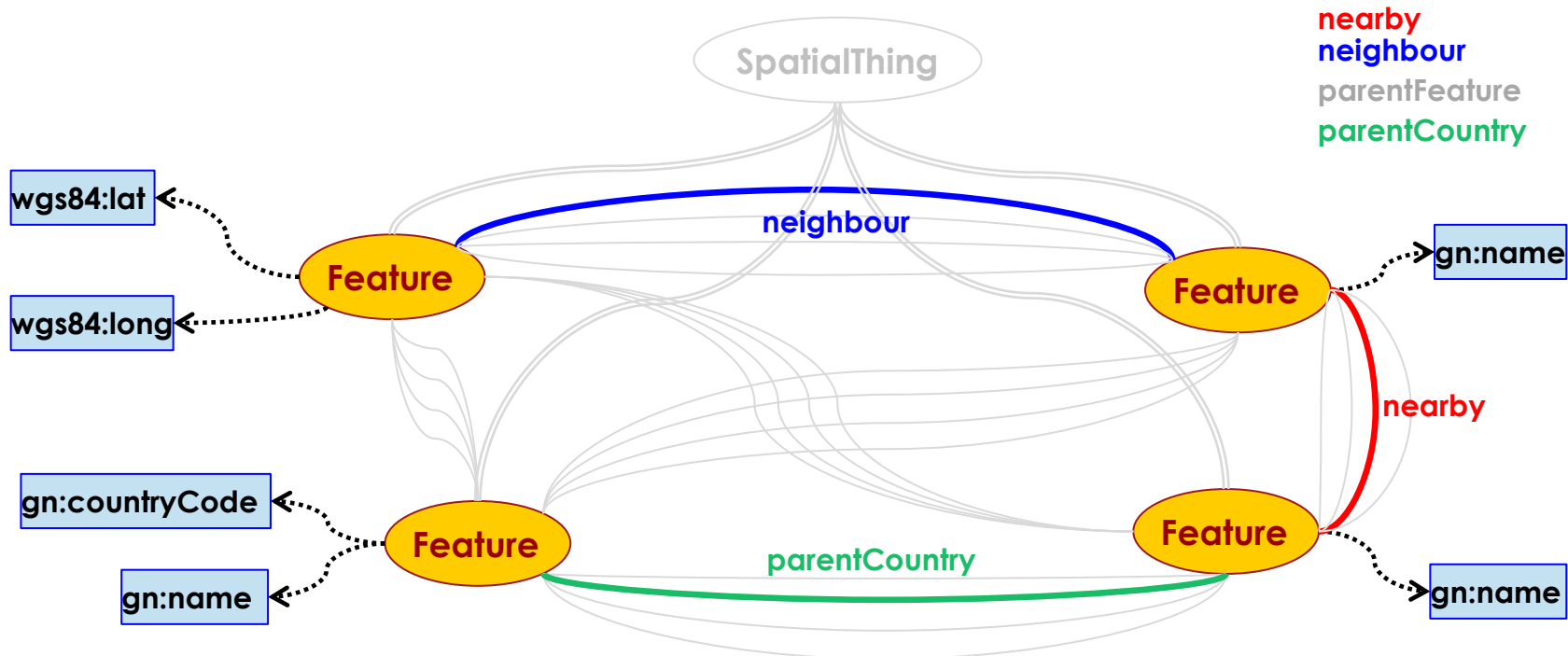
(gn:countryCode, gn:Feature)

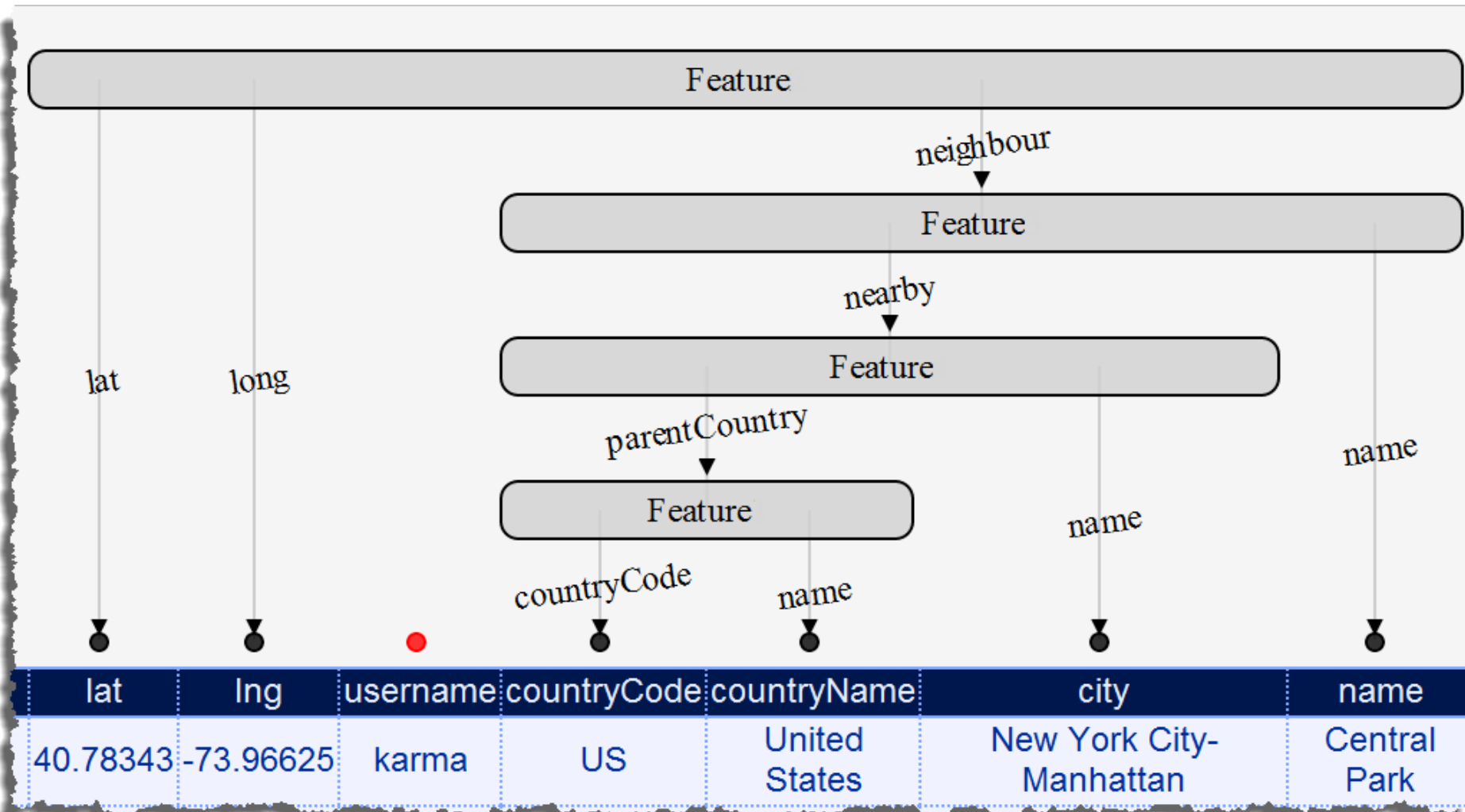


- Construct a graph from semantic types and ontology graph
- Select minimal tree that connects all semantic types
 - A customized **Steiner tree algorithm**



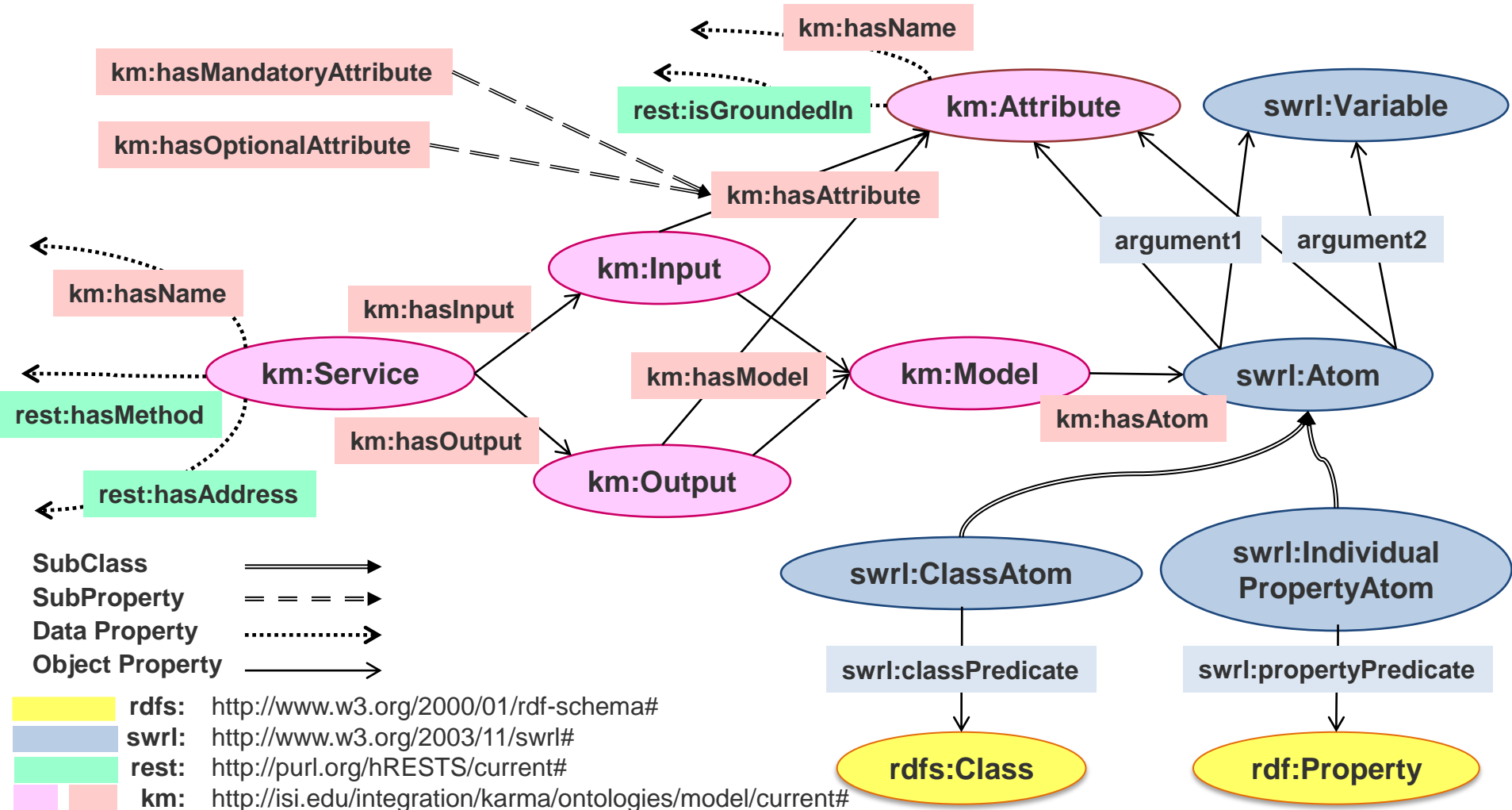
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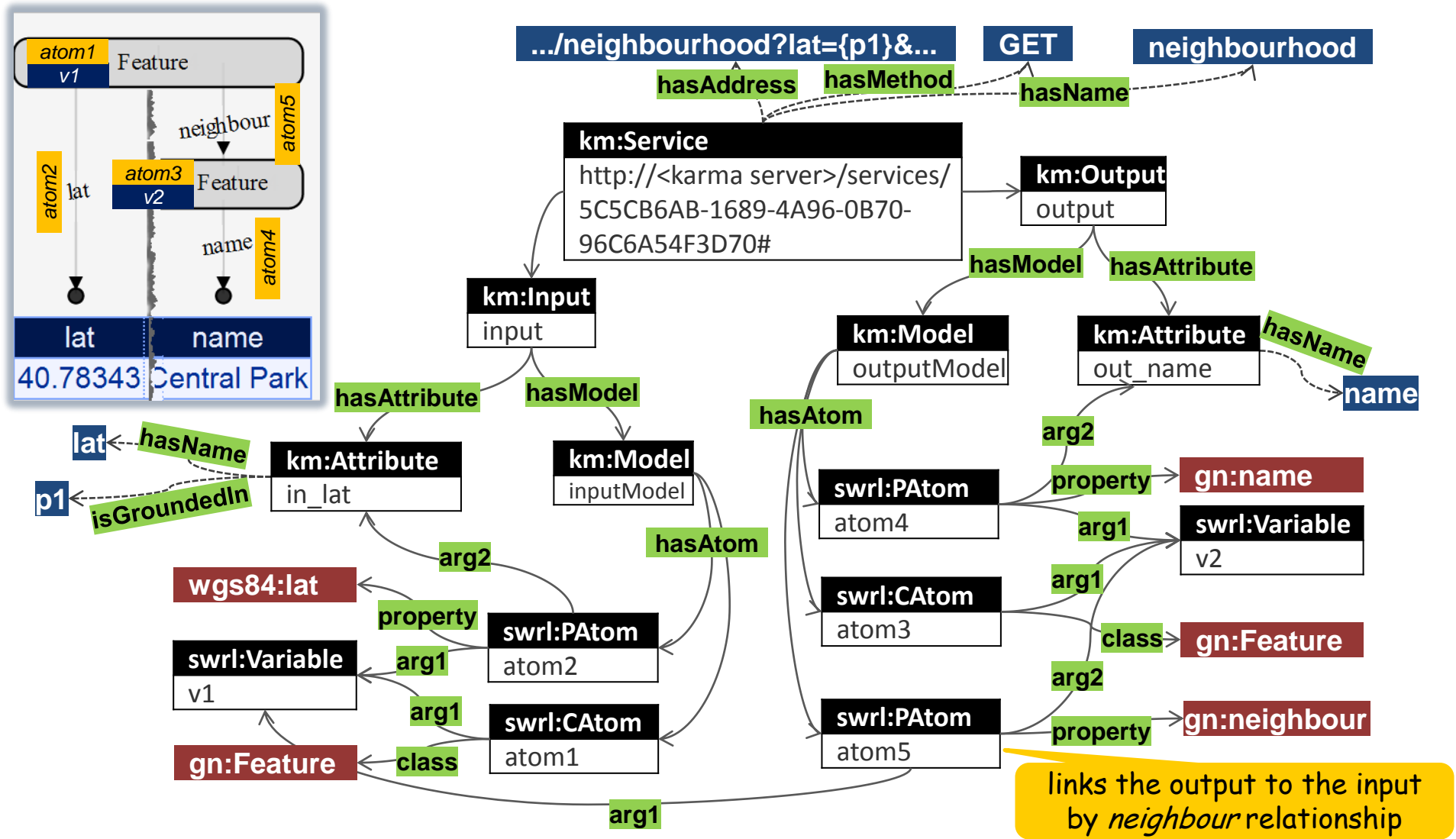


- Rapidly Integrating APIs with the LD
 - Building API Semantic Model
 - **Representing API Descriptions**
 - Building Linked APIs
- Evaluation
- Related Work
- Conclusion & Future Work

Service Modeling Ontology



Example: Service Description

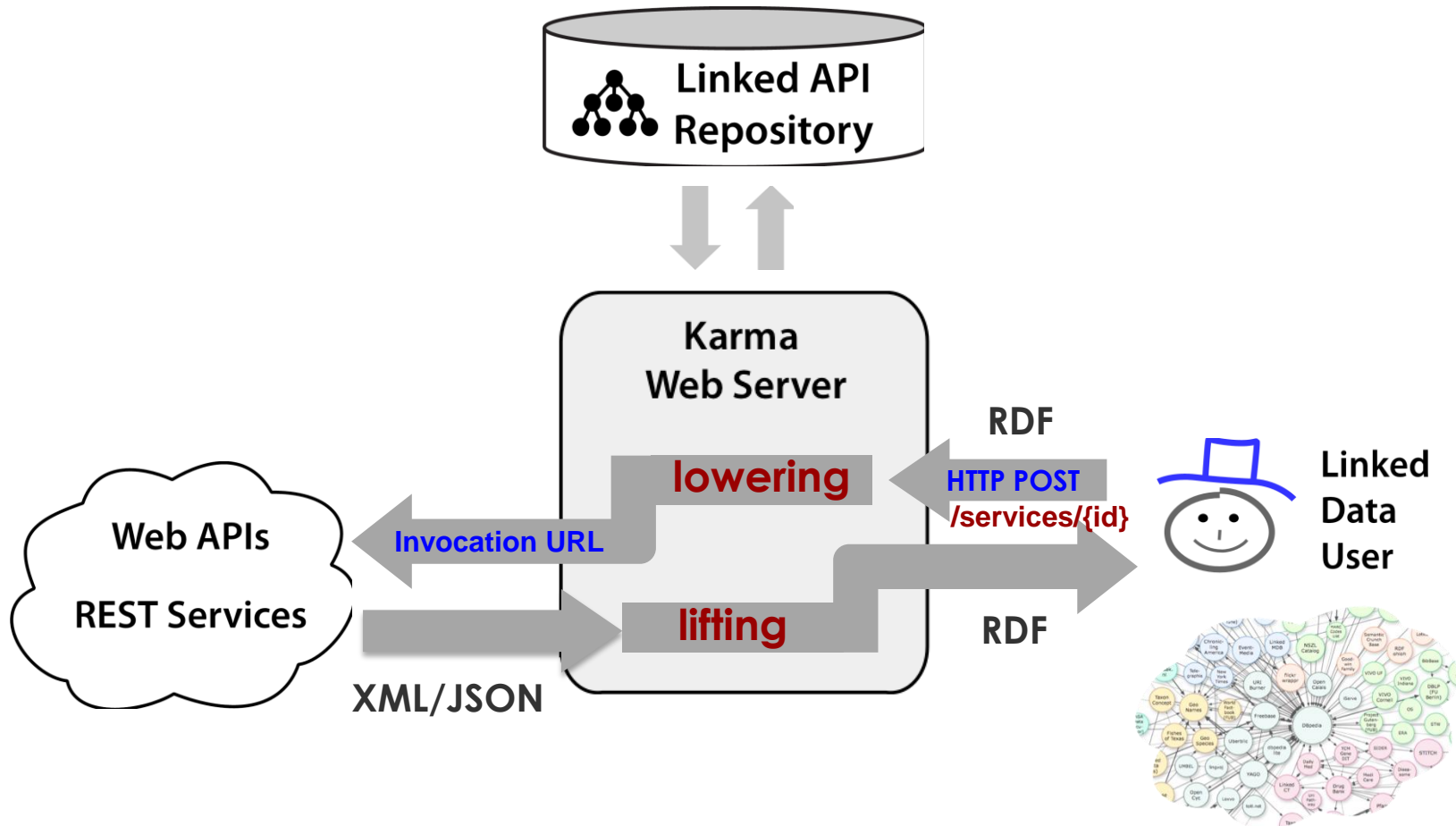


- Find services that return the neighbor feature given the latitude and longitude
-

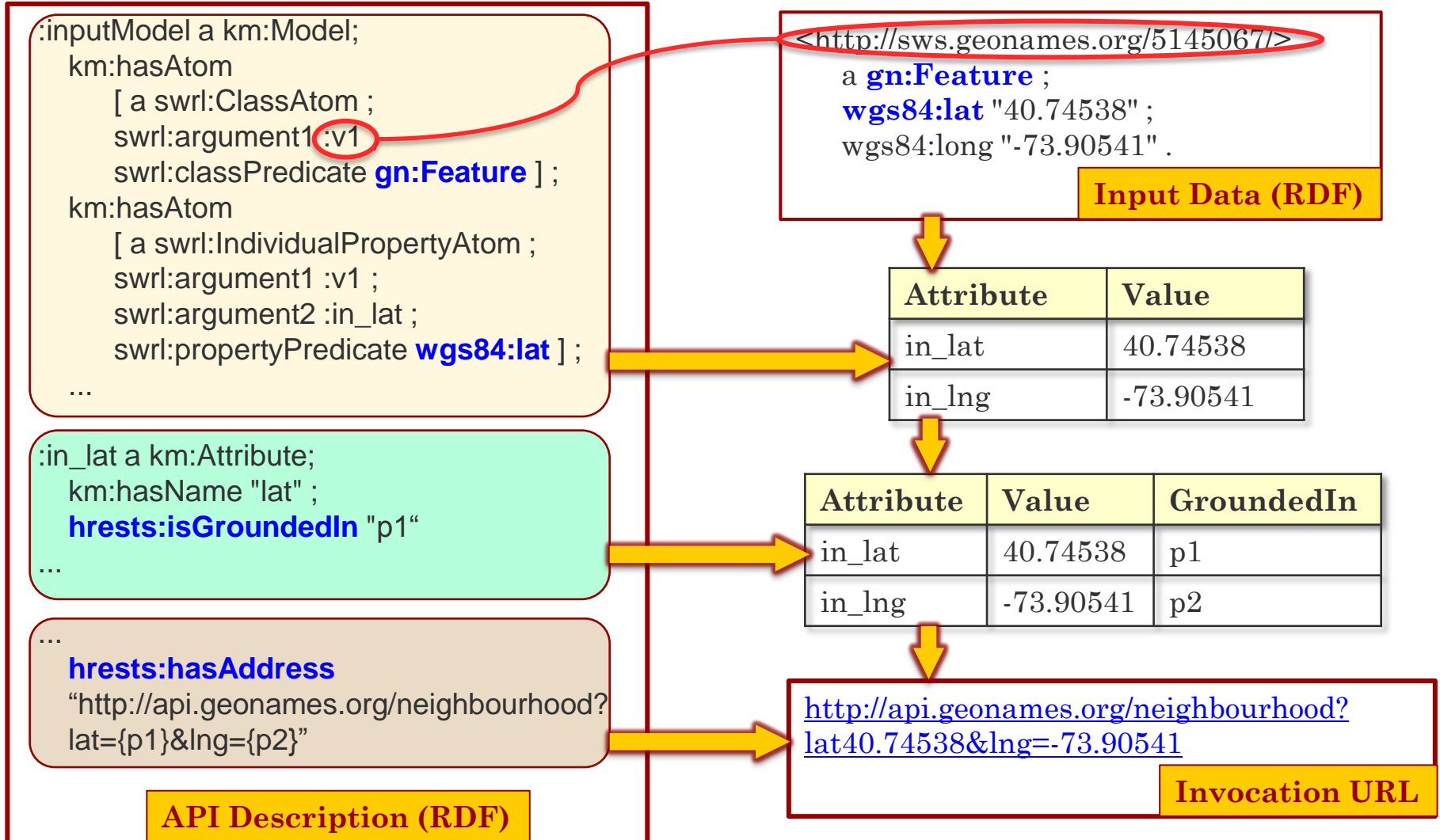
```
SELECT ?s WHERE {  
  ?s km:hasInput [km:hasAttribute ?i1, ?i2].  
  ?s km:hasOutput [km:hasAttribute ?o1].  
  ?s km:hasInput [km:hasModel [km:hasAtom  
    [swrl:classPredicate gn:Feature; swrl:arg1 ?f1],  
    [swrl:propertyPredicate wgs84:lat; swrl:arg1 ?f1; swrl:arg2 ?i1],  
    [swrl:propertyPredicate wgs84:long; swrl:arg1 ?f1; swrl:arg2 ?i2]]].  
  ?s km:hasOutput [km:hasModel [km:hasAtom  
    [swrl:classPredicate gn:Feature; swrl:arg1 ?f2],  
    [swrl:propertyPredicate gn:neighbour; swrl:arg1 ?f1; swrl:arg2 ?f2]]]}
```


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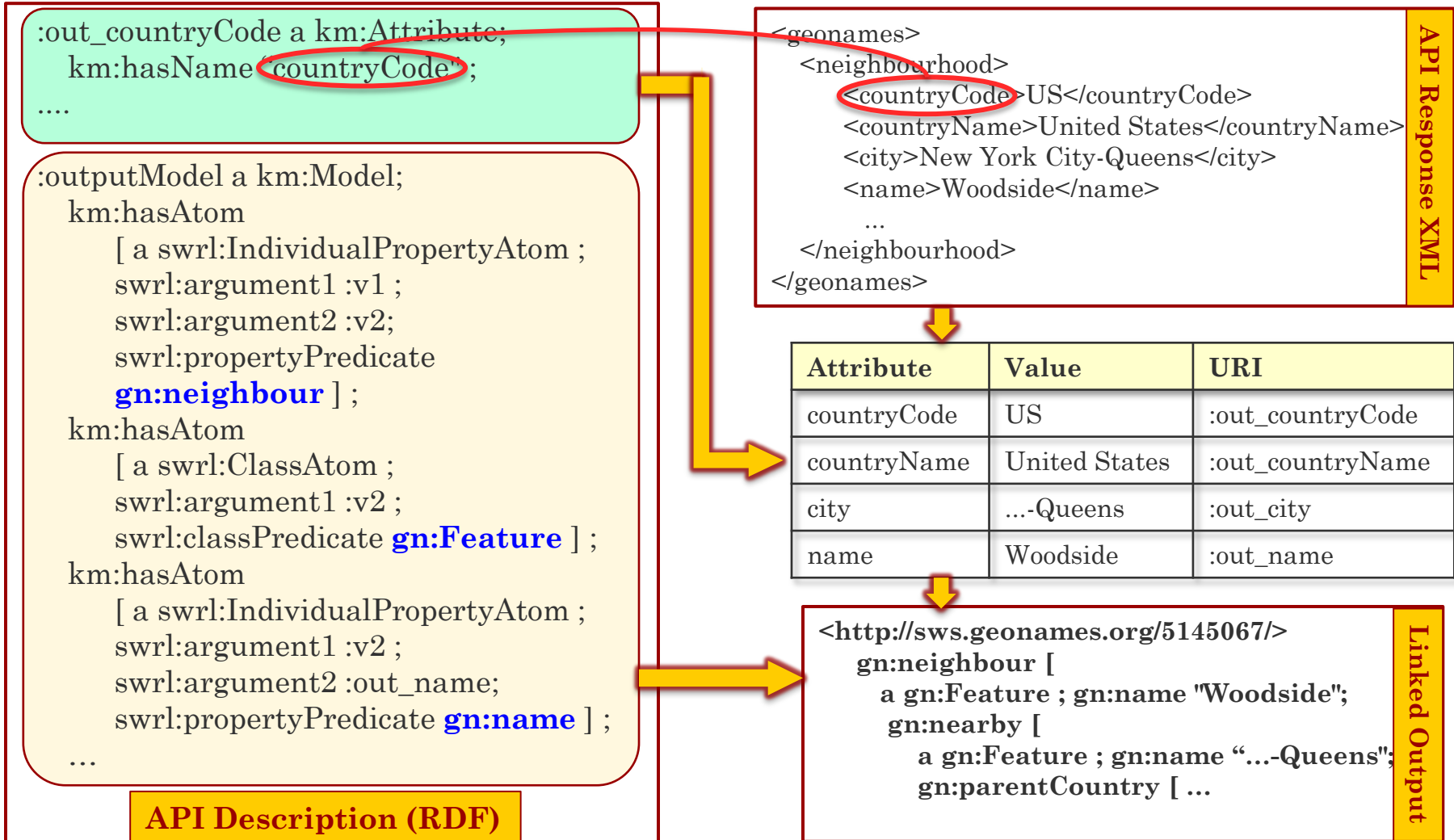
Invoking Linked APIs (POST)



Lowering



Lifting



- Rapidly Integrating APIs with the LD
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Evaluation

Geonames API	#Examples	#Columns	Time (min)
<i>neighbourhood</i>	3	10	6
<i>neighbours</i>	2	9	5
<i>children</i>	2	10	3
<i>sibling</i>	1	9	3
<i>ocean</i>	2	3	1
<i>findNearby</i>	3	11	3
<i>findNearbyPostalCodes</i>	3	11	7
<i>findNearbyPOIsOSM</i>	3	7	3
<i>findNearestAddress</i>	3	14	6
<i>findNearestIntersectionOSM</i>	3	8	3
<i>postalCodeCountryInfo</i>	1	5	2
Total	26	97	42

Average 4 minutes to build a linked API

- Linked Services [Pedrinaci & Domingue, 2010]
 - Annotates inputs and outputs by concepts from ontologies
 - Publishes service descriptions into the LOD cloud using Minimal Service Model (MSM)
 - Cannot represent relationships between service attributes
- Linked Open Services (LOS) [Krummenacher & Norton & Marte, 2010], Linked Data Services (LIDS) [Speiser & Harth, 2010]
 - SPARQL graph patterns to describe inputs and outputs
 - Service discovery is not straightforward
- RESTdesc [Verborgh et al, 2012]
 - N3 logical rules to capture API functionality

- Linked Services [Pedrinaci & Domingue, 2010]
 - Annotates inputs and outputs by concepts from ontologies
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Karma semi-automatically builds service descriptions and the modeling process does not require expertise in SW technologies

- Linked Data Service (LDS) [Pedrinaci, 2010]
 - SPARQL graph patterns to describe inputs and outputs
 - Service discovery is not straightforward
- RESTdesc [Verborgh et al, 2012]
 - N3 logical rules to capture API functionality

- Rapidly build rich semantic models of services
- Publish service descriptions into the LD cloud
- Provide strong support for service discovery and composition
- Build linked APIs that consume and produce linked data

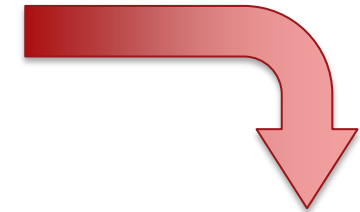
- Apply our approach on REST-like URLs
 - <http://www.ex.com/weather/CA/Los Angeles>
- Compose data and services in Karma

S1(address → street, city, state, zipcode,)

S2(city, state → temperature, windspeed, ...)

S3(zipcode, distance → hotel, ranking)

Composition



events	
name	address
ACM GIS 2012	300 N. Harbor Drive Redondo Beach, CA 90277
ISWC 2012	50 Park Plaza at Arlington Street, Boston, MA 02116

Show: 10 20 50 records Previous Next

- More information/papers/software/demos:
 - <http://www.isi.edu/integration/karma/>
- Contact
 - Mohsen Taheriyani: mohsen@isi.edu
 - Craig Knoblock: knoblock@isi.edu
 - Pedro Szekely: pszekely@isi.edu
 - Jose Luis Ambite: ambite@isi.edu