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ANALYTICS AND DATA SUMMIT 2020

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No Nonsense.

February 25-27, 2020

# Enhancing Statistical Discovery with Oracle RDF on Oracle Cloud

Shoki Nishimura, National Statistics Center of Japan
Yusuke Takeyoshi, Senior Principal Consultant, Oracle Japan

National Statistics Center
NSTAC

# Agenda

- ✓ Background
  - Introduction of e-Stat System
  - Why We Developed LOD
  - How We Configured e-Stat LOD
  - Integrating GeoSpatial RDF Data in e-Stat LOD
  - Sample Application (Demo)
- ✓ Technical Details of e-Stat LOD
  - LOD System Architecture
  - Size and Scale of e-Stat LOD
  - SPARQL Performance Concerns
  - Database Design to Improve Performance

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  - **Integrating GeoSpatial RDF Data in e-Stat LOD**
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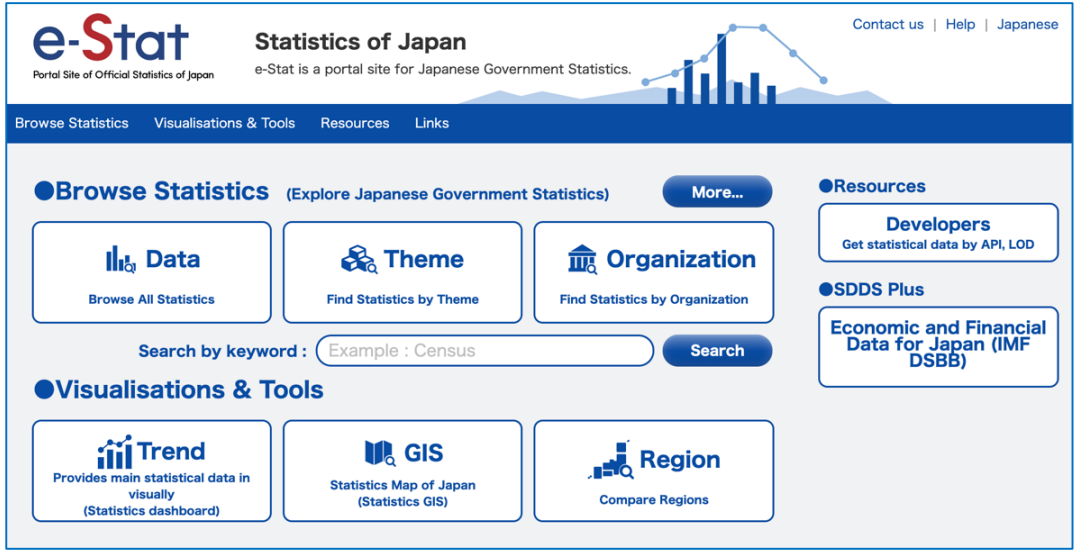
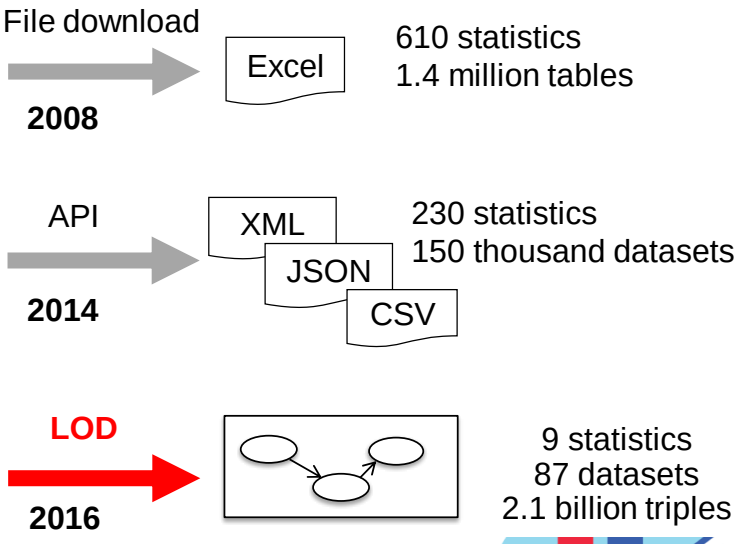
  - SPARQL Performance Concerns
  - Database Design to Improve Performance

# Introduction of e-Stat System
## - Portal Site for Official Statistics of Japan

- In 2008, e-Stat started to publish statistical data of government agencies (Format: Excel)
- In 2014, API service started (Format: XML, JSON, CSV)
- **In 2016, LOD (Linked Open Data) service started (Format: RDF)**




e-Stat (https://www.e-stat.go.jp/)

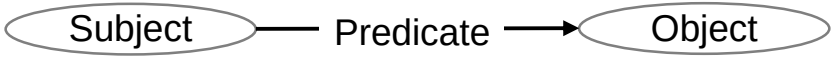


# What is RDF and LOD?

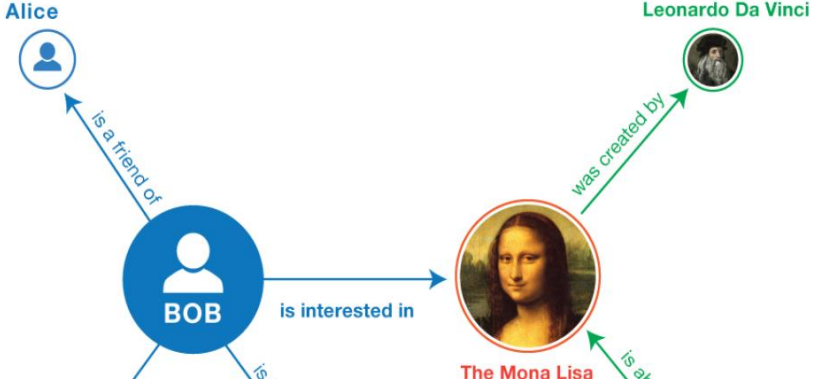
## RDF (Resource Description Framework)

- RDF is a standard model for data interchange on the web.
- RDF uses **URIs** to name the relationship as well as the two ends of the link (this is usually referred to as a **Triple**).

***Structure of Triple***

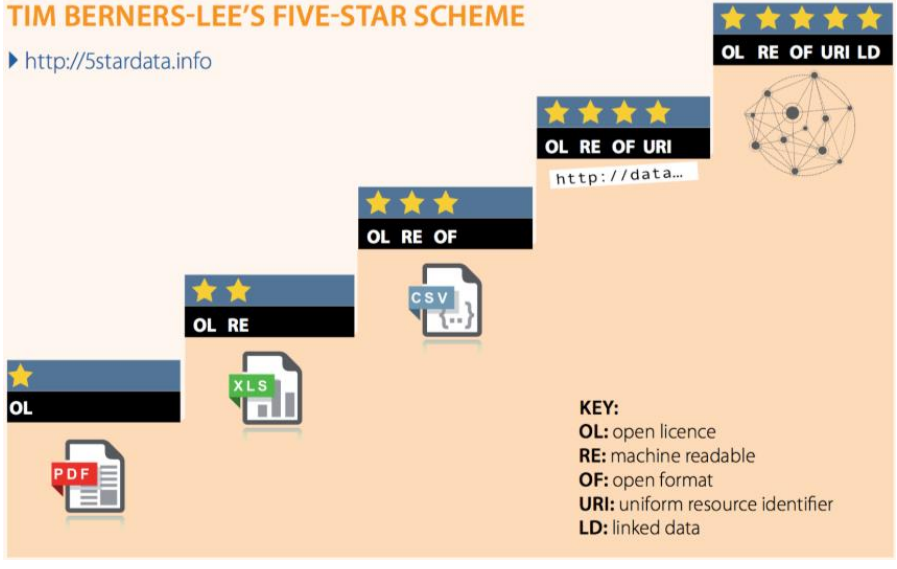



***Structure of RDF Graph***




## LOD (Linked Open Data)

- LOD is structured open data interlinked with other data.
- LOD builds on RDF technologies.



# Why We Developed LOD

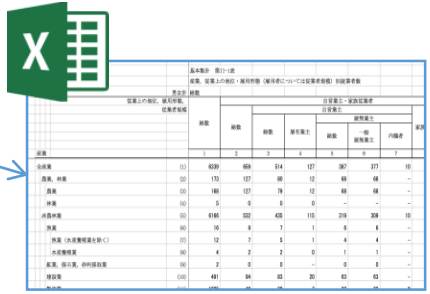
From *"Link to File"* To *"Link to Data"*

Clarify semantics and origins for data

## Link to File

**Assign URI to page**
(http://www.e-stat.go.jp/pages.html)


**Assign URI to file**
(http://www.e-stat.go.jp/xls0001.xls)



## Link to Data

| Sex / Age / Standard area code | Total (Sex) | | | Male | | |
|---|---|---|---|---|---|---|
| | ... | 44 years [Person] | 45 years [Person] | ... | 44 years [Person] | 45 years [Person] |
| ... | ... | ... | ... | ... | ... | ... |
| Saitama-city | ... | 16,130 | 19,245 | ... | 8,293 | 9,938 |
| Kawaguchi-city | ... | 6,582 | 8,022 | ... | 3,526 | 4,289 |
| ... | ... | ... | ... | ... | ... | ... |

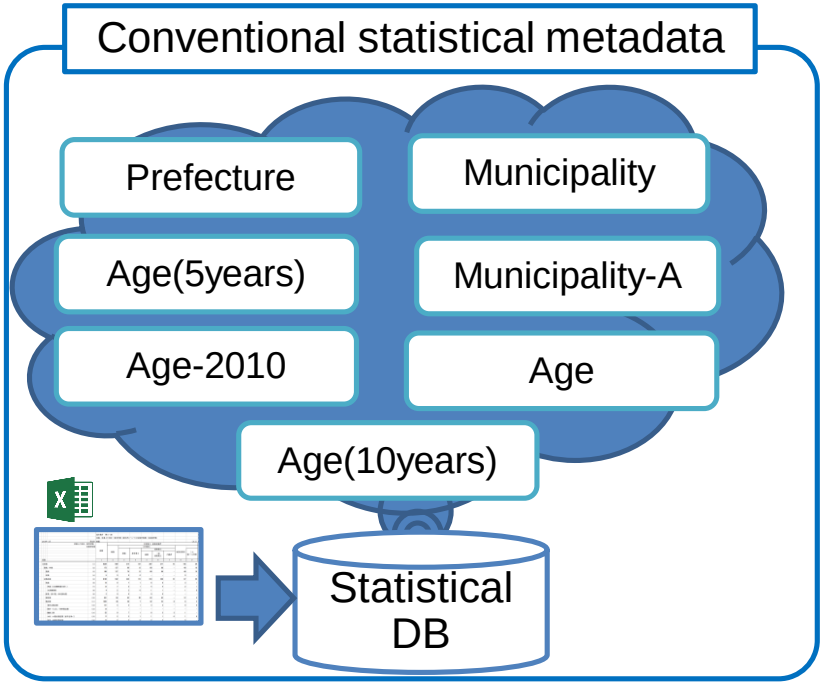
**Assign URI to each data**
(http://data.e-stat.go.jp/lod/…/obs00001)

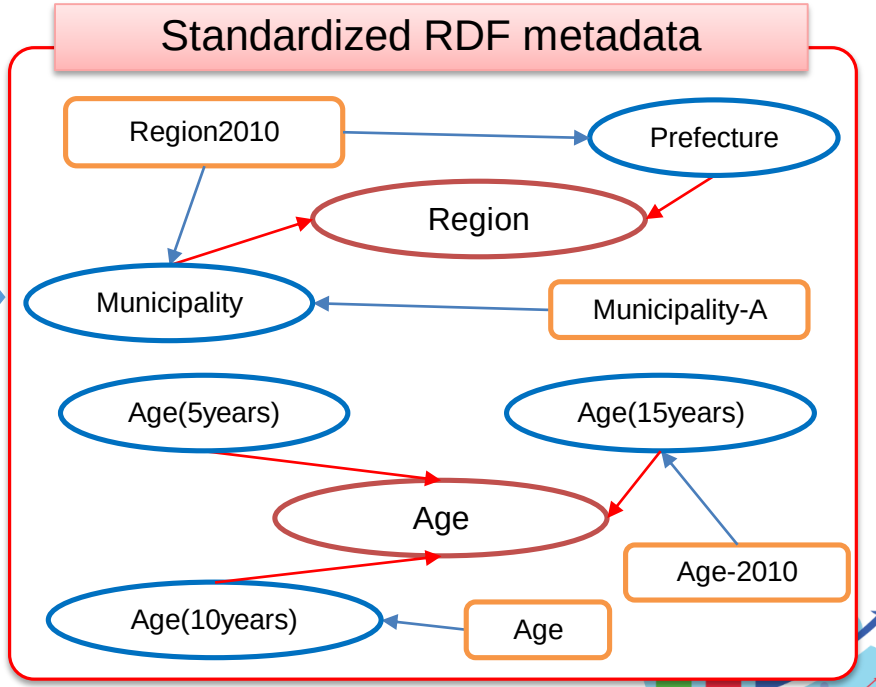
**Assign URI to each data**
(http://data.e-stat.go.jp/lod/…/C11201)

# Why We Developed LOD

Metadata for statistical data in Japan is not standardized, which makes it hard to process data.

➡ Define standardized metadata as **RDF** to make it machine-readable



# How We Configured e-Stat LOD

## Example: The population of 44-year-old men in Kawaguchi City in 2010

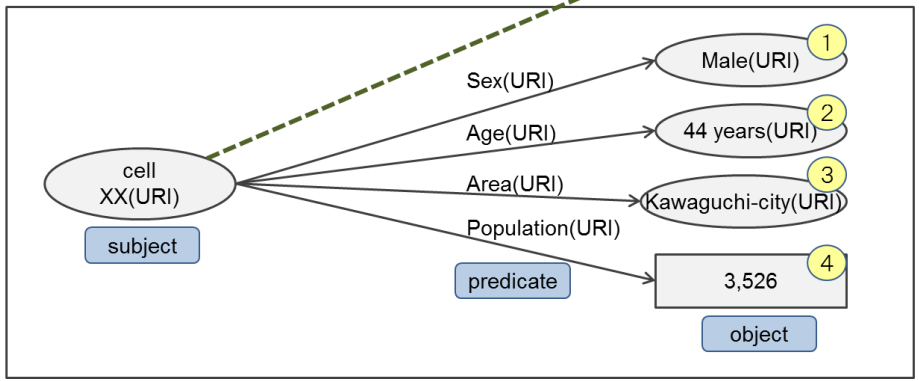
**Original Excel format**

e.g. Population of 2010 Population census

| Sex / Age / Standard area code | ... | Total (Sex) 44 years [Unit Of Person] | Total (Sex) 45 years [Unit Of Person] | ... | ... | Male ① 44 years ② [Unit Of Person] | Male 45 years [Unit Of Person] | ... | Female ... |
|---|---|---|---|---|---|---|---|---|---|
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Saitama-city | ... | 16,130 | 19,245 | ... | ... | 8,293 | 9,938 | ... | ... |
| Kawaguchi-city ③ | ... | 6,582 | 8,022 | ... | ... | ④ 3,526 | 4,289 | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

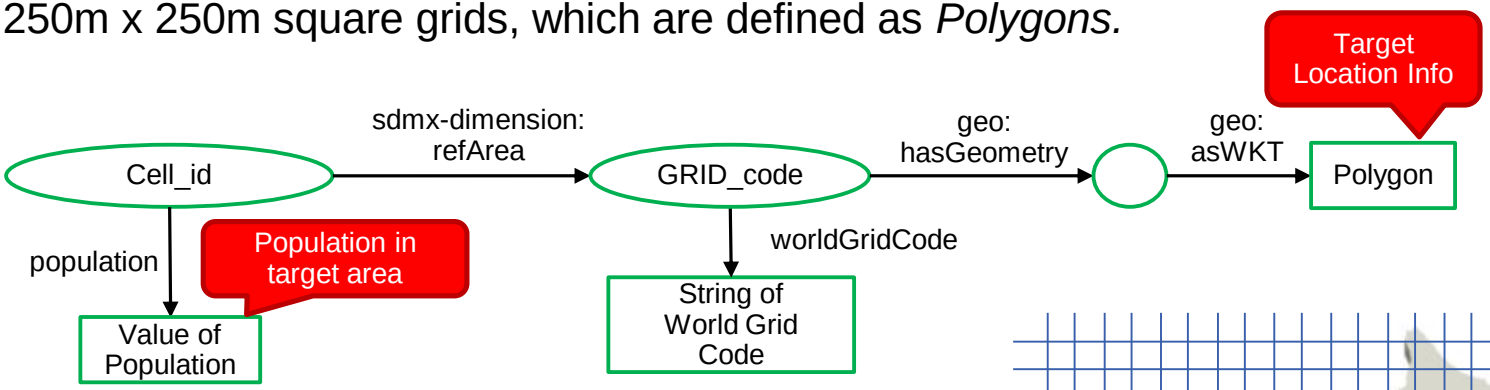
convert each observation values (cells) into RDF data

**Converted RDF format (R2RML)**



# Integrating GeoSpatial RDF Data in e-Stat LOD

Major statistics such as Population Census are integrated with more fine-grained location data, such as 250m x 250m square grids, which are defined as *Polygons.*

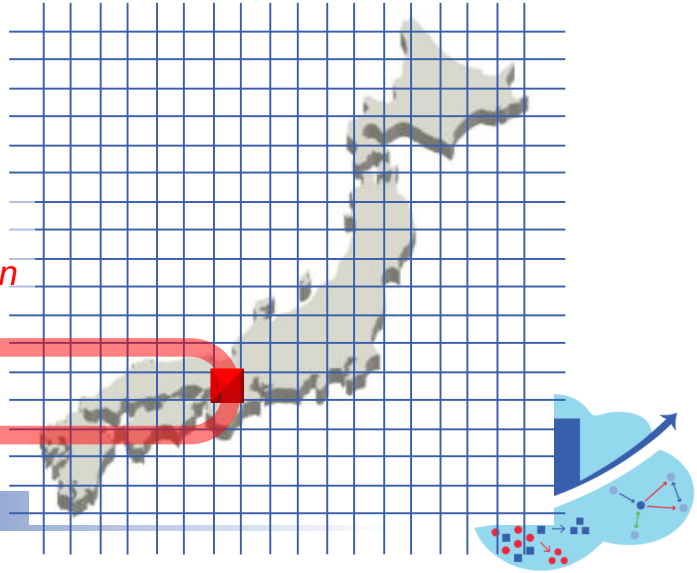



✓ Statistical data can be obtained with GeoSPARQL.

**Example of GeoSPARQL *FILTER* expression**

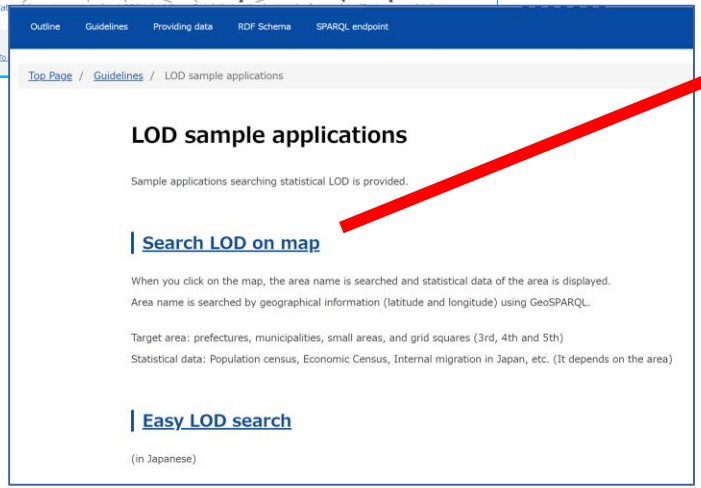
```
FILTER (
  ogcf:sfWithin(
    ?wkt ,
    "POLYGON(…)"^^geo:wktLiteral
  )
)
```

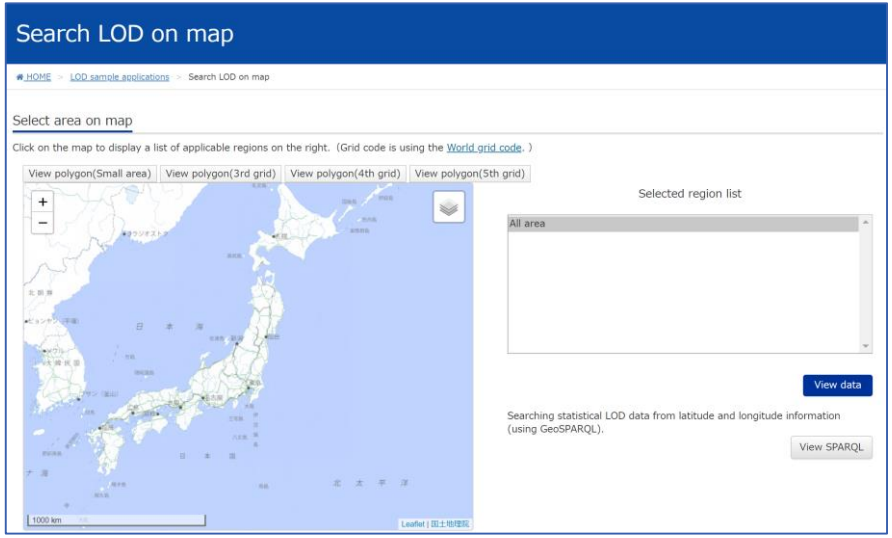
*Query population info WITHIN a search polygon*



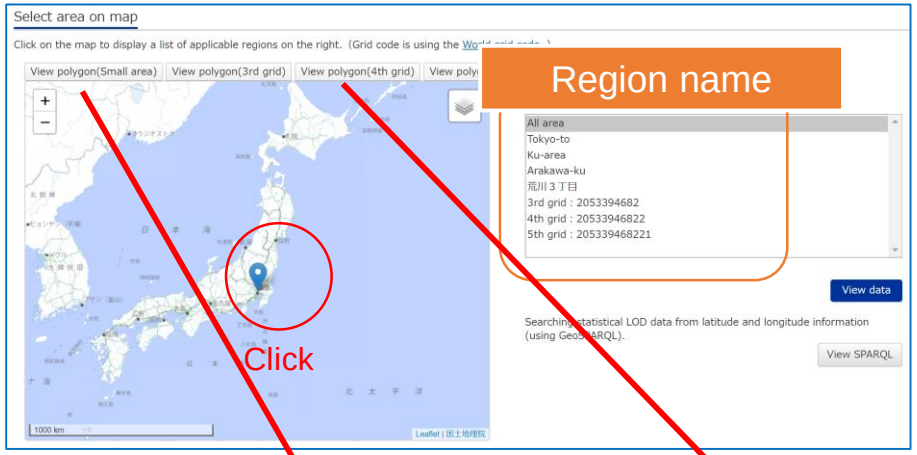
# Sample Application

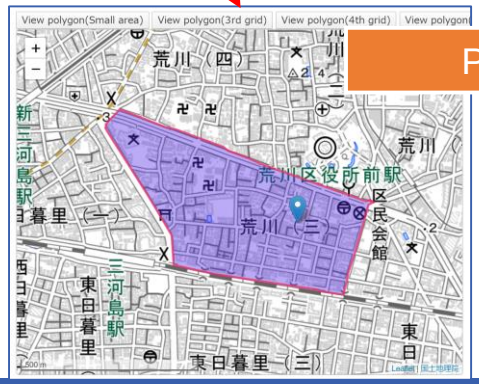
https://data.e-stat.go.jp/lodw/en/

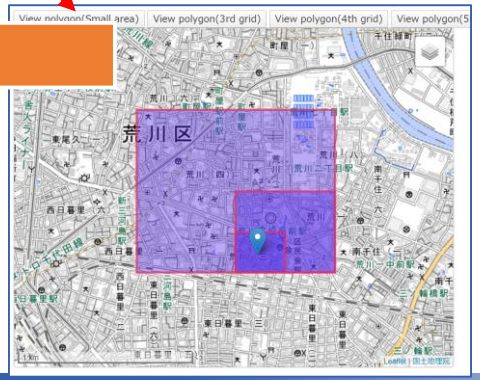



# Sample Application




Polygon




```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX ogcf: <http://www.opengis.net/def/function/geosparql/>
PREFIX dcterms: <http://purl.org/dc/terms/>

SELECT DISTINCT ?area ?areaName ?areaType ?areaId ?areaWKT
WHERE {
?area geo:hasGeometry / geo:asWKT ?areaWKT ;
a ?areaType ;
dcterms:identifier ?areaId ;
rdfs:label ?areaName .
FILTER (ogcf:sfContains(?areaWKT, 'Point(139.78247469054514
35.734430056624056)'^^geo:wktLiteral))
} LIMIT 10
```

GeoSPARQL

# Sample Application

select dataset

- Population and Households
  - Population
    - Population by sex - 5th level grid squares
    - Population by age and sex - 5th level grid squares
    - Foreigners by sex - 5th level grid squares
    - households by type of household - 5th level grid squares
    - Private households by size of household - 5th level grid squares
    - Private households by family type of household - 5th level grid squares
    - Private households by division of household member's age - 5th level grid squares
    - One-person private households by presence of household member 20-29 years of age - 5th level grid squares
    - Private households by type of household by presence of aged household members - 5th level grid squares

Select measure and dimension

- Dataset
  Population by sex - 5th level grid squares
- Measure
  - Population
- Dimension

| | |
|---|---|
| | All (Sex) |
| Sex | Male |
| | Female |

View count 100 View Data

select measure and dimension

View observation value

- Search result

| Sex | Time period | Area | Population(Unit of person) |
|---|---|---|---|
| All (Sex) | 2015 | 5th grid : 205339468221 | 2178 |
| Male | 2015 | 5th grid : 205339468221 | 1046 |
| Female | 2015 | 5th grid : 205339468221 | 1132 |

- SPARQL

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX qb: <http://purl.org/linked-data/cube#>
PREFIX qb: <http://purl.org/linked-data/cube#>
PREFIX cd-dimension: <http://data.e-stat.go.jp/lod/ontology/crossDomain/dimension/>
PREFIX sdmx-dimension: <http://purl.org/linked-data/sdmx/2009/dimension#>
PREFIX estat-attribute: <http://data.e-stat.go.jp/lod/ontology/attribute/>
PREFIX sac: <http://data.e-stat.go.jp/lod/sac/>
PREFIX dcterms: <http://purl.org/dc/terms/>

SELECT DISTINCT
    ?selectedMeasure1
    ?selectedMeasureUnit1
    ?selectedMultUnit1
```

Download

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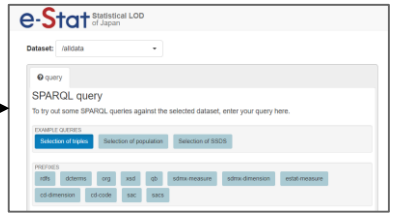
  - **LOD System Architecture**
  - **Size and Scale of e-Stat LOD**
  - **SPARQL Performance Concerns**
  - **Database Design to Improve Performance**

# LOD System Architecture

## Oracle Gen2 Cloud

- Production env. for **e-Stat "LOD" system**
- **Publishes RDF data** generated on the on-premise Exadata

### Fuseki SPARQL Endpoint




LOD User

Compute Cloud

Service monitoring

Management Cloud

Database Cloud
Extreme Performance
(BareMetal instance)

18c

## On-Premise (Exadata)

- Production env. for basic **e-Stat systems**
- Publishes statistical data in relational tables
- **Generates RDF data** from relational tables

e-Stat Databases

Transform tables to RDF (R2RML)

Oracle Database

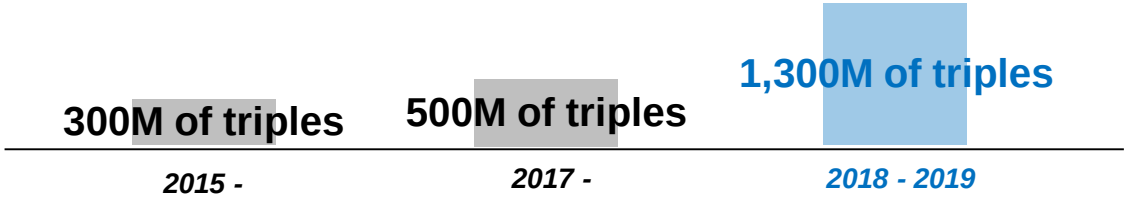
12c

e-Stat User

Transfer RDF files

# SPARQL Performance Concerns

✓ In 2018, triples increased to 1,300 million (including GeoSpatial data).
- At that time, the e-Stat LOD was running on on-premise Exadata 12cR2.




✓ SPARQL performance became no longer acceptable…
- Tested 138 different SPARQL queries (including several GeoSPARQL)

| | Exadata 12cR2 |
|---|---|
| Avg. SPARQL response time | 65.74 secs |
| Number of queries running over 10 sec. | 108 |
| Number of queries running over 300 sec. | 13 |

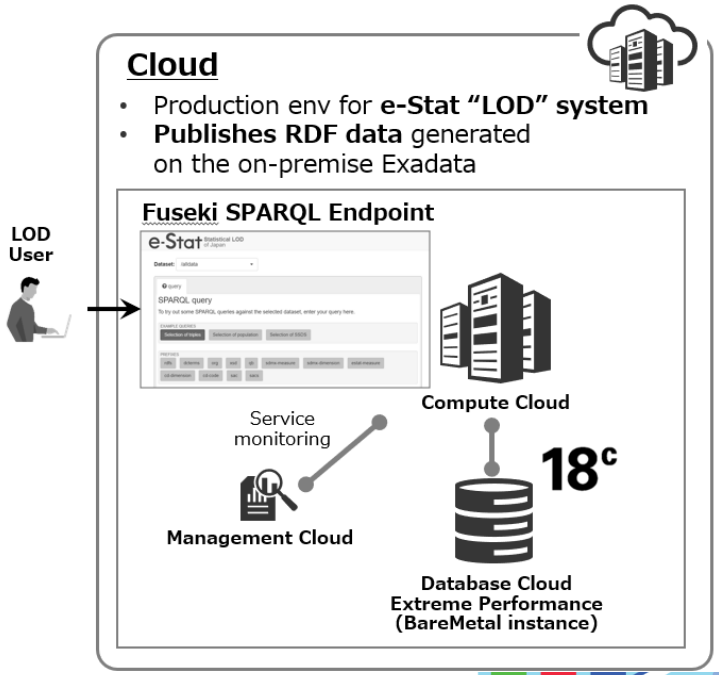
► **We needed a drastic measures to improve SPARQL performance!**

# Database Design to Improve Performance

The following tuning drastically improved query performance.

1. Using Database In-Memory features
2. Partitioning RDF table by triple “predicate”
3. Optimizing Optimizer Statistics based on actual SPARQLs

***Tuning 1, 2 are only available from Oracle 18c.***



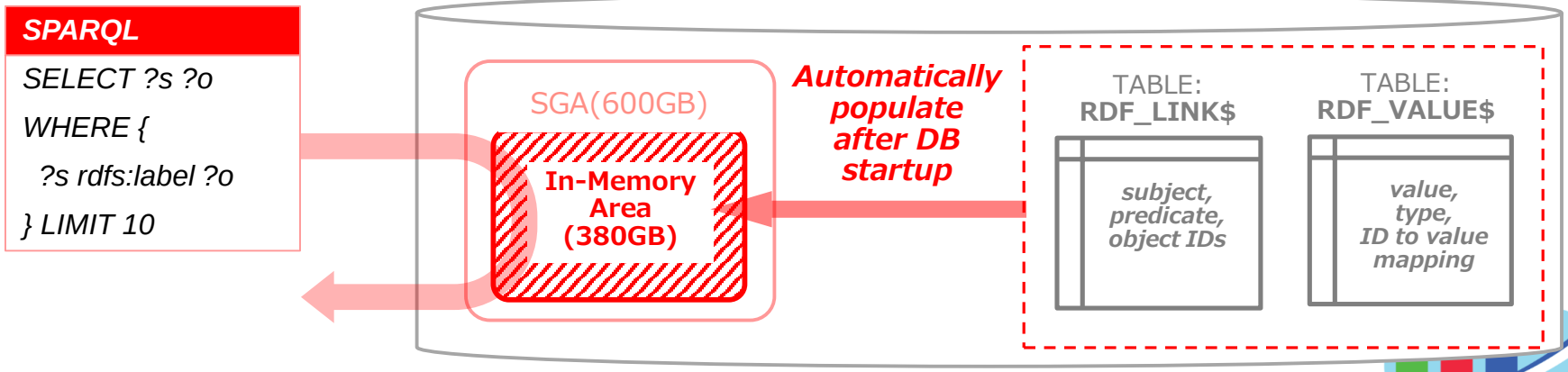
# 1. Using Database In-Memory Features

**DB In-Memory (DBIM)** improved SPARQL performance **by 10 to 60 times**.

✓ Enabling DBIM for RDF is very simple.

```
exec SEM_APIS.ENABLE_INMEMORY(TRUE);
```

✓ To reduce the amount of data accessed:
- The populated data is *automatically* compressed in memory
- In-Memory Indexes *automatically* prunes the data accessed



# 2. Partitioning RDF Table by Triple “predicate”

In many cases, graph patterns in SPARQL queries specify “predicate” URI and query “object” values.

**subject (variable)**

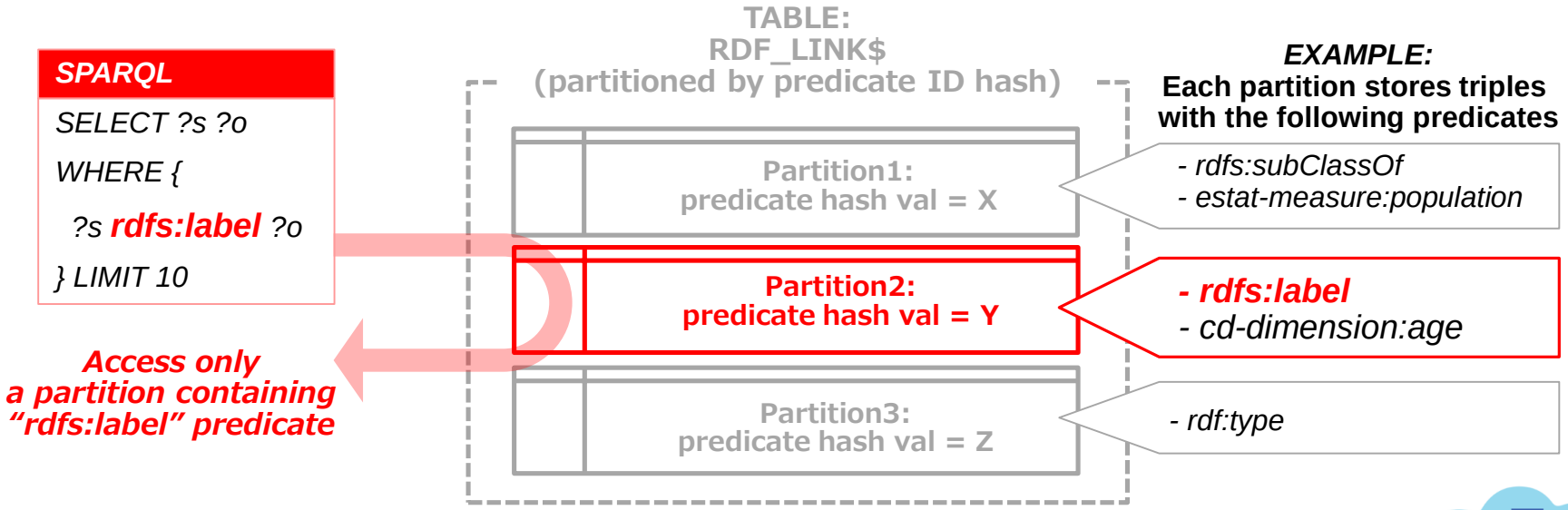
**predicate (URI specified)**

**object (variable, literal, URI)**

```
select  ?year ?population
where {
 ?s estat-measure:population ?population;
    sdmx-dimension:refArea / rdfs:label 'Kyoto-shi'@en ;
    cd-dimension:timePeriod ?year ;
    cd-dimension:sex cd-code:sex-all ;
    cd-dimension:nationality cd-code:nationality-japan ;
    g00200521-dimension-2010:area g00200521-code-2010:area-all ;
    cd-dimension:age cd-code:age-all .
}
```

# 2. Partitioning RDF Table by Triple “predicate”

To reduce the amount of data accessed,
we partitioned the RDF_LINK$ table using hash values of the RDF predicate IDs.



# 3. Optimizing Optimizer Statistics

In Oracle Database, RDF triples are stored in relational tables (RDF_LINK$, RDF_VALUE$, …), so SPARQLs are translated and executed as semantically the same SQLs.

- Optimizer Statistics are very important to generate optimal execution plans.

*Examples of Optimizer Statistics*

RDF_LINK$

*subject, predicate, object IDs*

RDF_VALUE$

*value, type, ID to value mapping*

**Number of rows**

**Avg. row length**

**Distinct num of values in each column**

*e.t.c.*

Optimizer makes optimal execution plans considering statistics

- Full Table Scan or Index Scan ?
- JOIN order
- JOIN method (LOOP or HASH ?)

*e.t.c.*

# 3. Optimizing Optimizer Statistics

For the optimizer to make a good execution plan against complex SPARQL queries, we gathered **column group statistics,** which enables optimizer to consider a correlationship between different columns.
Which column group statistics are useful was determined using **SPARQLs actually executed so far in the e-Stat LOD**.

STEP1: Tell the database to monitor column group usage for the specified seconds.

```
exec DBMS_STATS.SEED_COL_USAGE(NULL, NULL, 600);
```

STEP2: Execute as many SPARQLs as possible, which are executed so far, within the specified time

STEP3: Mark the useful column groups detected during the monitoring

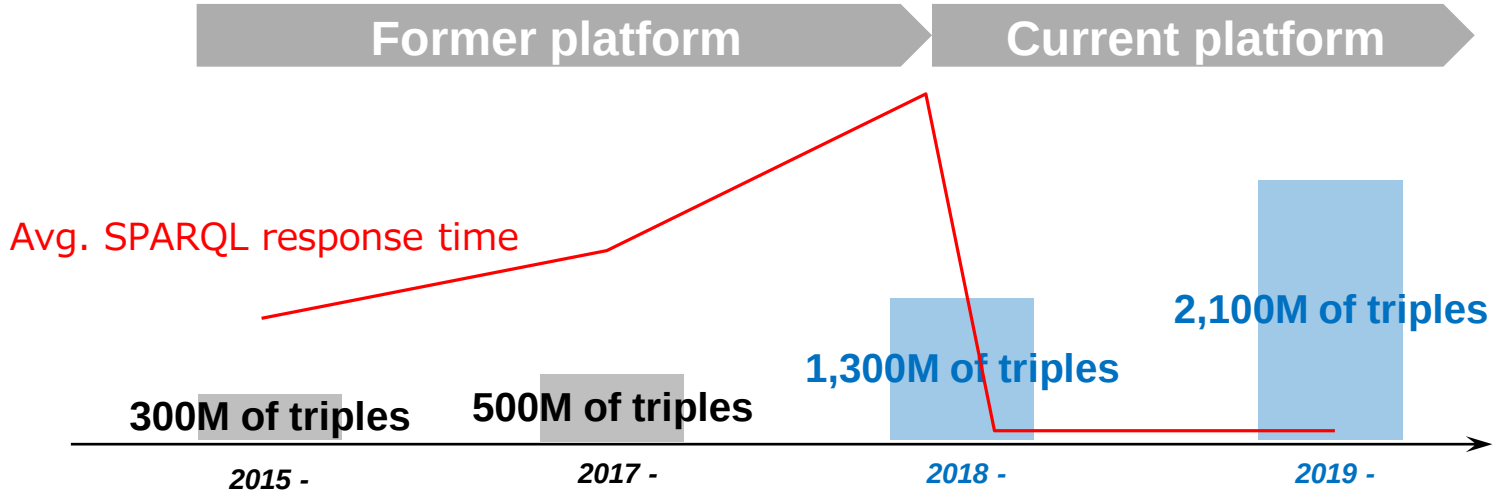
```
SELECT DBMS_STATS.CREATE_EXTENDED_STATS('MDSYS', 'RDF_LINK$') FROM DUAL;
```

STEP4: Gather statistics by a pre-built procedure SEM_PERF.GATHER_STATS.
The marked column group statistics are automatically gathered.

```
exec SEM_PERF.GATHER_STATS(…);
```

# How Much SPARQL Performance Improved?

| *Tested 138 different SPARQL queries against 1.3 billion triples (including several GeoSPARQL)* | On-prem Exadata Oracle 12cR2 (former platform) | **Oracle Gen2 Cloud Oracle 18c with tunings** |
|---|---|---|
| Avg. SPARQL response time | 65.74 sec. | **1.27 sec.** |




*The performance remained constant, even after triples increased to 2.1 billion!*

# Summary / Key Takeaways

- ✓ Publication of the 1st statistical LOD in Japan
  - 9 major statistics are published as LOD with Oracle Cloud
  - RDF triples are generated by use of R2RML from relational tables
  - GeoSpatial triples are integrated and published as LOD

- ✓ Performance improvement for SPARQL queries
  - We achieved 50 times faster performance applying the following changes:
    - Migrating the entire LOD platform to Oracle Gen2 Cloud
    - Utilizing DBIM features
    - Partitioning a RDF table by triple predicate
    - Gathering column group statistics

# Questions & Answers

# ANALYTICS AND DATA SUMMIT 2020

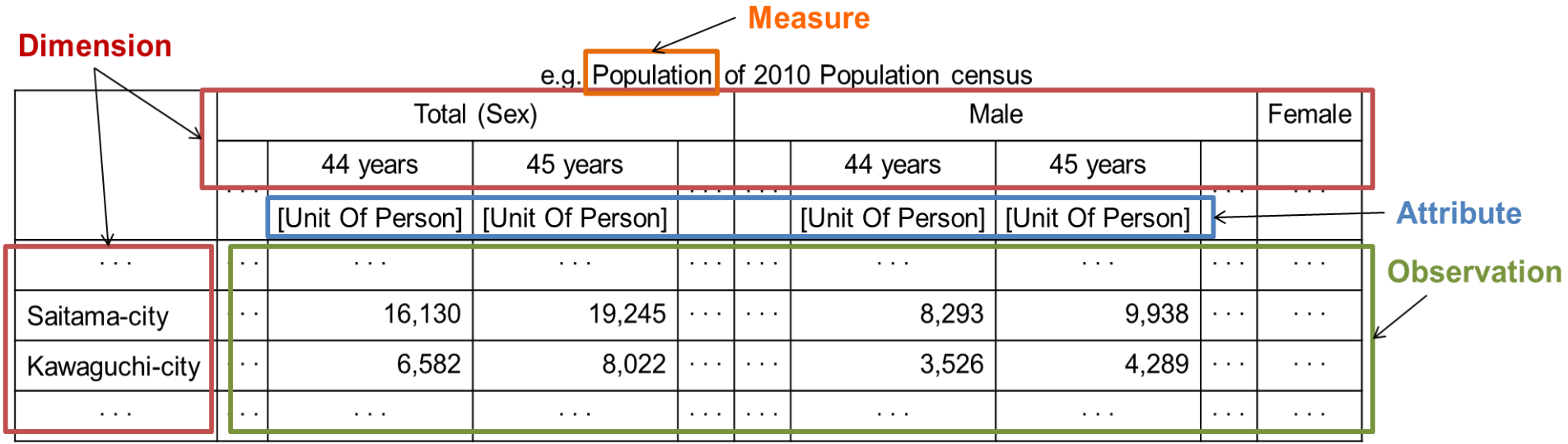
## All Analytics. All Data. No Nonsense.

February 25-27, 2020

# How We Configured e-Stat LOD

Data in e-Stat LOD is defined using **RDF Data Cube Vocabulary (W3C)**

- The RDF Data Cube Vocabulary provides a way to publish multi-dimensional statistics in such a way that it can be linked to related data sets and concept, (https://www.w3.org/TR/vocab-data-cube/).
- Each observation, or data in each cell, is described by dimensions, measures, and attributes.



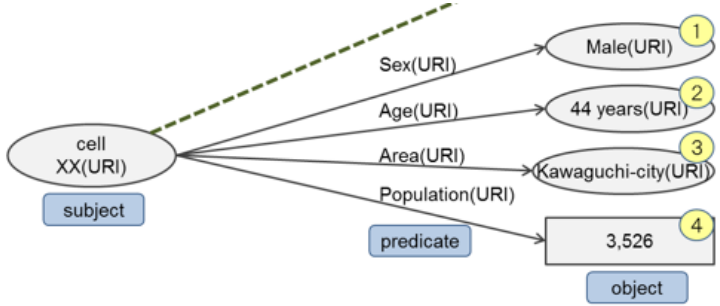

| | Total (Sex) | | | Male | | | Female |
|---|---|---|---|---|---|---|---|
| | 44 years | 45 years | | 44 years | 45 years | | |
| | [Unit Of Person] | [Unit Of Person] | | [Unit Of Person] | [Unit Of Person] | | |
| Saitama-city | 16,130 | 19,245 | | 8,293 | 9,938 | | |
| Kawaguchi-city | 6,582 | 8,022 | | 3,526 | 4,289 | | |

# How We Configured e-Stat LOD

RDF data was generated from statistics tables in our database with **R2RML** (R2RML = **R**DB to **R**DF **M**apping **L**anguage).

Statistics Tables
(Relational tables)

***Transform tables to RDF format (R2RML)***

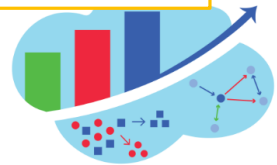



*Example of R2RML mapping file*

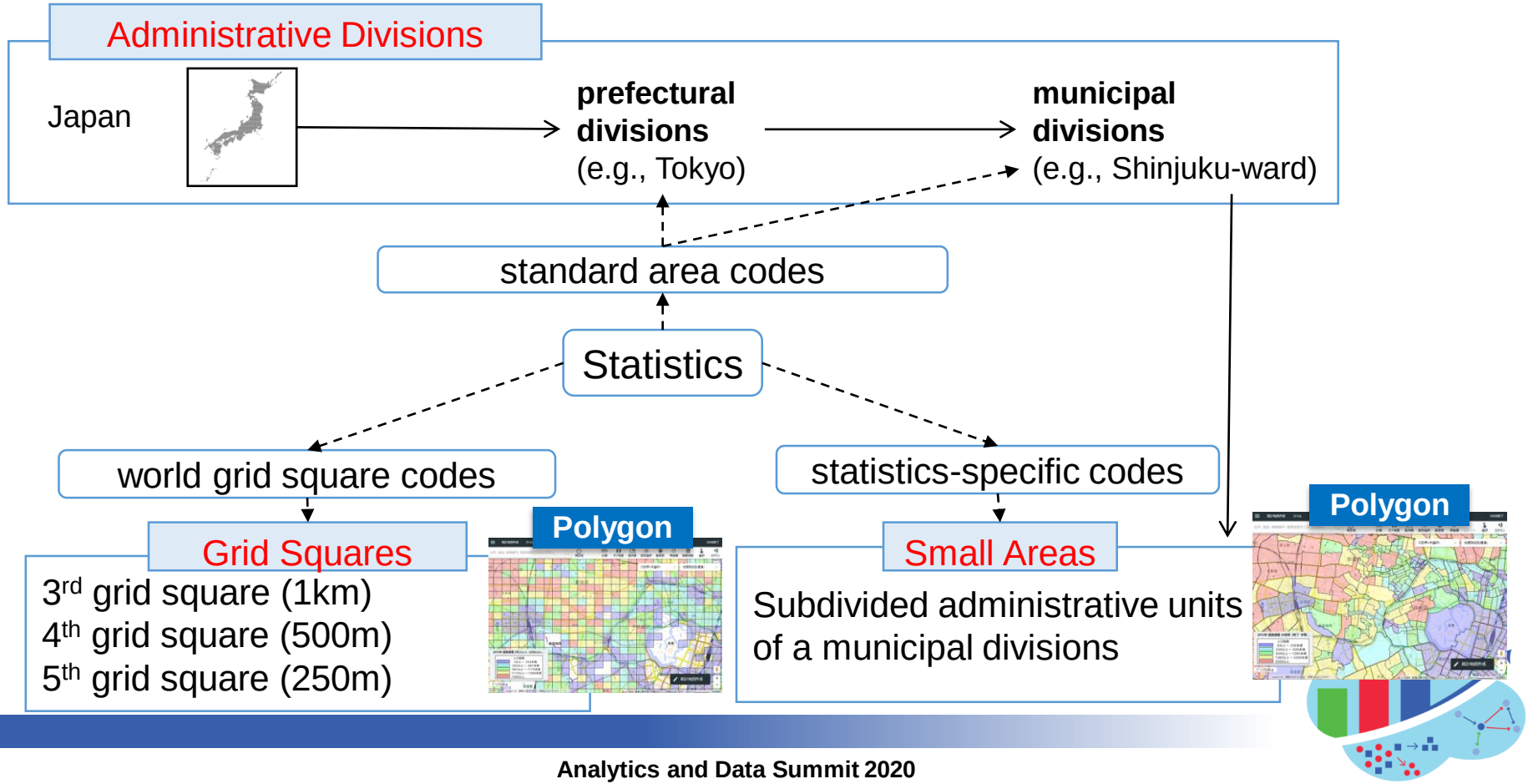
```
@prefix rr: <http://www.w3.org/ns/r2rml#>.
@prefix ex: <http://example.com/ns#>.

<#TriplesMap1>
    rr:logicalTable [ rr:tableName "EMP" ];
    rr:subjectMap [
        rr:template "http://data.example.com/employee/{EMPNO}";
        rr:class ex:Employee;
    ];
    rr:predicateObjectMap [
        rr:predicate ex:name;
        rr:objectMap [ rr:column "ENAME" ];
    ].
```

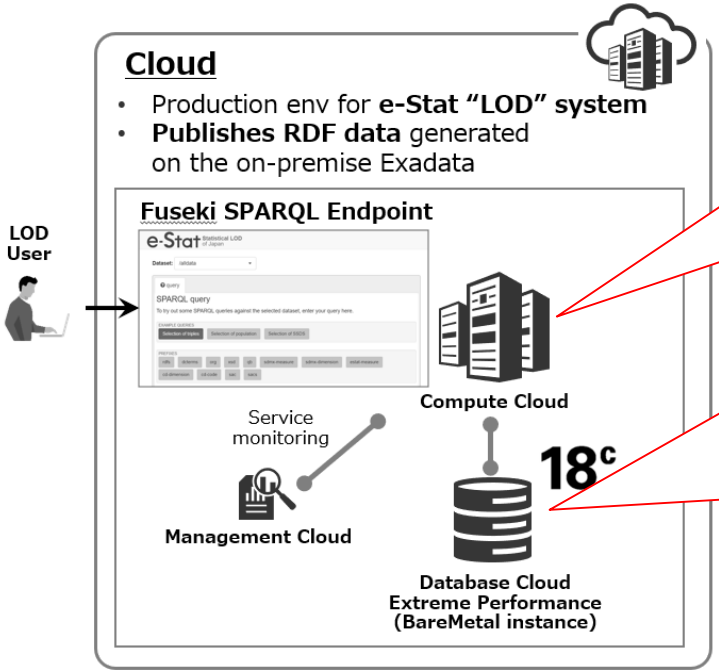
R2RML defines:
- Base table(s) / view(s)
- Rules that map each row in the base table to RDF triples



# Integrating GeoSpatial RDF Data in e-Stat LOD



# Size and Scale of e-Stat LOD (as of today)




## AP Tier

Fuseki on Jetty (x2 VM instances)

- CPU: 8 cores
- RAM: 120 GB

## DB Tier

Oracle Database Extreme Performance

- CPU: 12 cores
- RAM: 754 GB
- BareMetal Instance
- Number of Triples: 2.1 billion

# 1. Using Database In-Memory Features

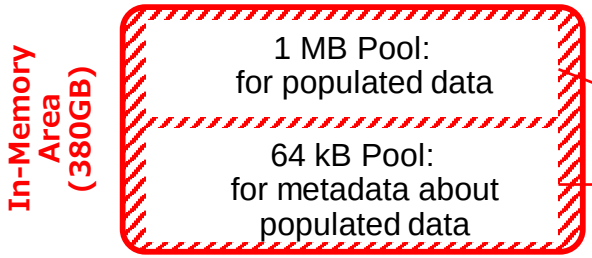
## DB In-Memory Settings for e-Stat LOD

- ✓ 380GB In-Memory Area (SGA = 600GB)
- ✓ Set the RDF semantic network indexes to INVISIBLE for the optimizer


Two semantic network indexes are created on RDF_LINK$ table by default.

- Index 1: Predicate - Object – Subject
- Index 2: Predicate - Subject - Object

- ✓ Minimize the area for METADATA to maximize the In-Memory area size for DATA
  - Set "_inmemory_64k_percent"=1 to reduce the metadata area to 1%




| POOL | ALLOC_GB |
|---|---|
| 1MB POOL | 356.8 |
| 64KB POOL | 22.9 |

99% for DATA

1% for METADATA

# 1. Using Database In-Memory Features

## Example: Tested SPARQL Query

Queries population census data in Kyoto City

```
select  ?year ?population
where {
 ?s estat-measure:population ?population;
    sdmx-dimension:refArea / rdfs:label 'Kyoto-shi'@en ;
    cd-dimension:timePeriod ?year ;
    cd-dimension:sex cd-code:sex-all ;
    cd-dimension:nationality cd-code:nationality-japan ;
    g00200521-dimension-2010:area g00200521-code-2010:area-all ;
    cd-dimension:age cd-code:age-all .
}
```

| year | population |
|---|---|
| "2015"^^xsd:gYear | "1412924"^^xsd:decimal |
| "2010"^^xsd:gYear | "1408039"^^xsd:decimal |

**WITHOUT** DB In-Memory

7.1 sec

**WITH** DB In-Memory

**0.58 sec**

**12x faster**

# 2. Partitioning RDF Table by Triple “predicate”

Partitioning Settings for e-Stat LOD

✓ Hash-Partitioning RDF_LINK$ can be done when creating a semantic network.

```
BEGIN
      SEM_APIS.CREATE_SEM_NETWORK(
            '< tablespace name for semantic network >',
            options=>' MODEL_PARTITIONING=BY_HASH_P MODEL_PARTITIONS=64 '
      );
END;
/
```

✓ The number of partitions = 64
- Partitioning by Hash should be done by a power of 2 (2, 4, 8, 16, 32, 64, 128, …) to equally distribute the number of triples in each partition.
- In e-Stat LOD, the distinct number of predicates is 144.