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# Introduction

One of the major features of the Semantic Reasoning Function (SMF) as described in clause 8.7 is to enhance/optimize existing semantic operations supported by oneM2M (such as semantic resource discovery or semantic query, etc.).

In the existing solution in clause 8.7.6.1, the original Invovled Data Basis (IDB) is further augmented by the inferred facts produced by a semantic reasoning operation. Then, the original SPARQL statement is to be executed on the “Augmented IDB”. In other words, in this solution, the SPARQL statement will not be modified.

In comparison, this contribution introduces an alternative solution to how the existing semantic operations (such as semantic query, semantic resource discovery, etc.) can be supported based on query statement modification. The key idea in this solution is to modify the original query statement based on the applicable reasoning rules. Accordingly, the modified query statement will be applied over the IDB in order to produce the result.

Table 1. Comparisons of Approaches for Initiating a Semantic Operation with Reasoning Support

|  |  |  |
| --- | --- | --- |
| **Approaches for Initiating a Semantic Operation with Reasoning Support** | **Pros** | **Cons** |
| Solution 1: IDB Augmentation through Semantic Reasoning  (now in clause 8.7.6.1 – see Change #1) | * A generic approach for supporting any query statement * Inferred facts obtained through semantic reasoning can be used to augment original IDB * Easy for implementation | * Extra overhead introduced by IDB augmentation * Long processing time for semantic operations if IDB augmentation is done in an online manner. |
| Solution 2: Query Modification w/o Semantic Reasoning  (now in clause 8.7.6.2 – see Change #2) | * Do not need to trigger a reasoning operation to get inferred facts * Only needs to utilize applicable reasoning rules to modify the original query | * Need to conduct the query modification when a new query is received * May not work for complex queries. |

### -----------------------Start of change 1-------------------------------------------

### 8.7.6 Initiating a Semantic Operation with Reasoning Support

This clause introduces solutions for how the existing semantic operations (such as semantic query, semantic resource discovery, etc.) can benefit from semantic reasoning.

In general, it is assumed that in addition to SR, there is also a Semantic Engine or SE (e.g., a SPARQL engine) in the system. Accordingly, an oneM2M user can send a request to the SE in order to initiate a specific semantic operation, in which a SPARQL statement is often included to describe user’s needs. For the SE, when processing a specific received request (e.g., a semantic resource discovery request), it needs to collect the Involved Data Basis (IDB), which is a set of RDF triples that the SPARQL statement is to be executed on. However, the original IDB without semantic reasoning support may not be perfect or well match with the SPARQL statement (e.g., the RDF triples in IDB are described using a different ontology than the ontology adopted in the SPARQL query statement sent from the user, see ontology mapping use cases in [i.16]). As a result, no result can be obtained when executing the SPARQL statement over the original IDB. When semantic reasoning is also supported in the system, one of potential enhancements is that the SE can further utilize the semantic reasoning capability provided by a SR (as a background support) in order to augment the original IDB with additional/implicit facts (i.e., the obtained reasoning result) and finally optimize the processing of the semantic operation at SE. In comparison, another alternative way is to modify the query statement of the semantic operation based on the applicable reasoning rules and the modified query statement will be executed on the original IDB. Those two solutions are described in clause 8.7.6.1 and 8.7.6.2 respectively.

#### 8.7.6.1 Solution 1: Initiating a semantic operation with reasoning support via IDB augmentation

#### 8.7.6.1.1 Procedure for initiating a semantic operation with reasoning support via IDB augmentation

Figure 8.7.6.1.1-1 illustrates the proposed procedure for initiating a semantic operation with reasoning support and the key idea is that by utilizing the reasoning capability, the original IDB determined by the SE will be further augmented by integrating inferred facts (i.e., the reasoning result) with the existing facts in the IDB. Accordingly, the SPARQL statement will be executed on the “Augmented IDB”. Figure 8.7.6.1.1-1 illustrates the proposed procedure and the detailed descriptions are as follows:

Step 1: An oneM2M User-1 intends to initiate a semantic operation, which may refer to a semantic query operation, a resource discovery operation, etc. Accordingly, User-1 will compose a request message, in which a corresponding SPARQL statement is also included.

Step 2: User-1 sends the request to SE-1 in order to initiate the intended semantic operation.

Step 3: Based on the request from User-1, SE-1 starts the related processing. The first step is to determine the IDB for this request, on which the SPARQL statement is to be executed.

Below are the two examples of IDB for two different semantic operations (one is for semantic resource discovery operation and the other is for semantic query operation):

* In case of semantic resource discovery, User-1 may send a resource discovery request to a semantic-capable CSE (hosting a SE) and the “To” parameter indicates where the discovery should start, e.g., a specific resource <Resource-1>. In particular, for each of the normal resources which is a descendant of <Resource-1> (e.g., <Resource-2>), its <semanticDescriptor> child resource (if exists) will be evaluated in order to decide whether <Resource-2> should be included in the discovery result. In other words, when evaluating a specific resource (e.g. <Resource-2>), its IDB includes the RDF triples stored in its <semanticDescriptor> child resource. Then, the SPARQL statement will be executed over its <semanticDescriptor> child resource (if exists) in order to decide whether <Resource-2> should be included in the discovery result.
* In case of semantic query, User-1 may send a semantic query request to a semantic-capable CSE (hosting a SE) and the “To” parameter may refer to a specific resource <Resource-1>, which also defines the query scope of this request. It means that all the semantic-related descendant resources (e.g., <semanticDescriptor> resources) of <Resource-1> are constituted as the IDB for this semantic query operation. This scope may be further enlarged if <semanticDescriptor> resources in scope are linked (e.g. via *relatedSemantics* attributes) with others, by adding the linked resources to the IDB. Accordingly, the SPARQL statement will be executed over the aggregated RDF triples collected from those semantic-related resources.

The SE-1 also needs to decide whether semantic reasoning should be used for processing this request, which may have but not limited to the following potential ways:

* Based on an explicit indication included in the request (e.g. SE-1 needs to provide a reasoning-based discovery result), SE-1 leverages the semantic reasoning procedure.
* Based on local policies, if certain conditions occur while processing the request on the original IDB. For example, no resources are found during the initial processing of a resource discovery SE-1 may be configured to further leverage semantic reasoning.
* If User-1 is a preferred user (e.g. SE-1 needs to provide high-quality discovery result to User-1), SE-1 may decide to further leverage semantic reasoning.
* SE-1 can also be configured such that as long as it finds certain ontologies or the interested terms/concepts/properties adopted in the RDF triples included in the original IDB or in the SPARQL statement, SE-1 may decide to further leverage semantic reasoning.

As a result, if SE-1 decides to leverage semantic reasoning based on the above approaches, it will further contact SR-1 (Note that, the SE-1 and SR-1 may be hosted on the same CSE or can also be hosted by different CSEs).

Step 4: SE-1 sends a request to SR-1 in order to initiate a semantic reasoning operation. SE-1 may also include in the request the Fact Set (FS), Reasoning Rule Set (RS) and relevant information such as ontology mapping information . For example, the original IDB determined during Step 3 is the initial inputFS for the reasoning operation to be done by SR-1.

Step 5: In addition to the inputs provided by SE-1, optionally SR-1 may also decide whether additional FS and/or RS can be used. Then, SR-1 will collect all the needed FSs and RSs.

Step 6: SR-1 executes a semantic reasoning operation and yields the inferred facts (denoted as inferredFS-1).

Step 7: SR-1 sends back the inferredFS-1 to SE-1.

Step 8: SE-1 integrates the inferredFS-1 with the original IDB to generate an “Augmented IDB”, and executes the SPARQL statement over the augmented IDB to yield the corresponding result for the intended semantic operation required by User-1.

Step 9: When completing the processing, SE-1 sends back the processing result to User-1.



Figure 8.7.6.1.1-1: Procedure for Initiating a Semantic Operation with Reasoning Support via IDB Augmentation

#### 8.7.6.1.2 Examples usage of procedure for initiating a semantic operation with reasoning support via IDB augmentation

In this clause, a real example shows how the procedure introduced in Figure 8.7.6.1.1-1 can be used. In particular, a hospital facility surveillance use case as illustrated in clause 8.7.2 is reused here.

In the hospital facility surveillance use case, due to the different usages of rooms, the hospital has defined several “Management Zones (MZ)” and each MZ likely comprises multiple rooms. For example, MZ-1 includes all the rooms that store blood testing samples.

Now, User-1 intends to retrieve real-time images from the rooms “belonging to a specific management zone (e.g., MZ-1)”. For this purpose, User-1 needs to first discover those related cameras using oneM2M semantic resource discovery mechanism. As a result, the following steps will be conducted (the steps shown below are as same as the steps shown in Figure 8.7.6.1.1-1):

Step 1: User-1 intends to initiate a semantic resource discovery operation. For example, User-1 is looking for cameras monitoring the rooms belonging to a specific management zone (e.g., MZ-1). The SPARQL query statement in this semantic resource discovery request can be written as follows:

SELECT ?device

WHERE {

?device is-a ex:Camera

?device monitors-room-in MZ-1

}

Step 2: User-1 sends a request to SE-1 in order to initiate an intended semantic resource discovery operation.

Step 3: Based on the request from User-1, SE-1 starts the related processing. The first step is to determine the IDB for this request, on which the SPARQL statement is to be executed.

In this example, it is assumed that now <Camera-11> is one of the candidate resources to be evaluated. When evaluating <Camera-11>, all the RDF triples stored in the <semanticDescriptor> child resource of <Camera-11> is the IDB (denoted as IDB-1). For example, IDB-1 may include the following two facts:

• Fact-1: Camera-11 is-a Camera

• Fact-2: Camera-11 is-located-in Room-232-of-Building-1

In the meantime, SE-1 is configured such that as long as it finds that building/room number and/or a specific predicate “is-located-in” appears in the RDF triples as included in the IDB, SE-1 may decide to further leverage semantic reasoning.

Step 4: SE-1 sends a request to SR-1 in order to initiate a semantic reasoning operation. SE-1 also indicates that IDB-1 is the input FS for the reasoning operation, which includes Fact-1 and Fact-2.

Step 5: In addition to the inputs provided by SE-1, SR-1 may also decide whether additional FS and/or RS can be used. In this example, SR-1 finds that there is a key word “is-located-in” in Fact-2 and a key word “is-managed-under” in the SPARQL statement, accordingly SR-1 may decide that MZ definition and room allocation knowledge may be beneficial for this semantic reasoning operation and should be utilized. In particular, this knowledge may include the following fact:

• Fact-3: Room-232-of-Building-1 is-managed-under MZ-1

For the same reason, SE-1 also decides the following reasoning result can be utilized:

• Rule-1: IF A is-located-in B && B is-managed-under C, THEN A monitors-room-in C

Step 6: SR-1 executes a semantic reasoning operation and yields the reasoning result. In particular, by using Fact-2, Fact-3 along with Rule-1, the following inferred fact can be obtained:

• Inferred Fact-1: Camera-11 monitors-room-in MZ-1

Step 7: SR-1 sends back the Inferred Fact-1 to SE-1.

Step 8: SE-1 integrates Inferred Fact-1 with the original IDB (i.e., Fact-1 and Fact-2) to generate an augmented IDB, and executes the SPARQL statement over the augmented IDB to yield the corresponding discovery result. In this example, there will be a match when executing the SPARQL statement over the augmented IDB (since now the Inferred Fact-1 can match the pattern “?device is-managed-under MZ-1” in the SPARQL statement and Fact-1 can match the pattern “?device is-a ex:Camera”) and therefore the URI of <Camera-11> will be included in the discovery result). After that, SE-1 completes the evaluation of <Camera-11> and will continue to evaluate the next candidate resource if exists.

Step 9: When completing the processing, SE-1 sends back the processing result to User-1. In this example, due to the utilization of semantic reasoning, the URI of <Camera-11> is included in the discovery result and sent back to User-1.

### -----------------------End of change 1-------------------------------------------

### -----------------------Start of change 2-------------------------------------------

#### 8.7.6.2 Solution 2: Initiating a semantic operation with reasoning support via query modification

#### 8.7.6.2.1 Procedure for initiating a semantic operation with reasoning support via query modification

In this alternative solution, the key idea is that by utilizing the reasoning capability, the original query statement specified in a semantic query or semantic resource discovery request will be modified. Accordingly, the modified query will be applied over the original IDB in order to produce the result. Figure 8.7.6.2.1-1 illustrates the proposed procedure and the detailed descriptions are as follows:

Step 1: Same as Step 1 in Figure 8.7.6.1.1-1.

Step 2: Same as Step 1 in Figure 8.7.6.1.1-1.

Step 3: Based on the request from User-1, SE-1 starts the related processing. The first step is to determine the IDB for this request, on which the SPARQL statement is to be executed. Then, SE-1 also needs to decide whether to leverage semantic reasoner SR-1 for the possible SPARQL query modification/re-writing.

Step 4: SE-1 sends a request to SR-1 in order to ask SR-1 to modify the original SPARQL query statement.

Step 5: SR-1 determines which reasoning rules that can be used for the request sent from SE-1. Optionally, the SR-1 can also decide which additional facts can be used for this request, if the original IDB is not sufficient.

Step 6: SR-1 modifies the original SPARQL statement based on the applicable reasoning rules.

Step 7: SR-1 sends back the modified SPARQL statement to SE-1. Alternatively, the SR-1 may send back all the applicable reasoning rules to SE-1 and let SE-1 conduct the query statement modification by its own.

Step 8: SE-1 executes the modified SPARQL statement over the IDB and yields the processing result.

Step 9: Same as Step 9 in Figure 8.7.6.1.1-1.



Figure 8.7.6.2.1-1: Procedure for Initiating a Semantic Operation with Reasoning Support via Query Modification

#### 8.7.6.2.2 Examples usage of procedure for initiating a semantic operation with reasoning support via query modification

In this clause, a real example shows how the procedure introduced in clause 8.7.6.2.1 can be used. In particular, a hospital facility surveillance use case as illustrated in clause 8.7.2 is a nice application scenario where the procedure proposed in clause 8.7.6.2.1 can be applied.

In the hospital facility surveillance use case, due to the different usages of rooms, the hospital has defined several “Management Zones (MZ)” and each MZ likely comprises multiple rooms. For example, MZ-1 includes all the rooms that store blood testing samples.

Now, User-1 intends to retrieve real-time images from the rooms “belonging to a specific management zone (e.g., MZ-1)”. In order to the so, User-1 needs to first discover those related cameras using oneM2M semantic resource discovery mechanism. As a result, the following steps will be conducted (the steps shown below are as same as the steps shown in Figure 8.7.6.2.1-1):

Step 1: User-1 intends to initiate a semantic resource discovery operation. For example, User-1 is looking for cameras monitoring the rooms belonging to a specific management zone (e.g., MZ-1). The SPARQL query statement in this discovery request will can be written as follows:

SELECT ?device

WHERE {

?device is-a ex:Camera

?device monitors-room-in MZ-1

}

Step 2: User-1 sends a request to SE-1 in order to initiate an intended semantic resource discovery operation.

Step 3: Based on the request from User-1, SE-1 starts the related processing. The first step is to determine the IDB for this request, on which the SPARQL statement is to be executed.

In this example, it is assumed that now <Camera-11> is one of the candidate resources to be evaluated. When evaluating <Camera-11>, all the RDF triples stored in the <semanticDescriptor> child resource of <Camera-11> is the IDB (denoted as IDB-1). For example, IDB-1 may include the following two facts:

• Fact-1: Camera-11 is-a Camera

• Fact-2: Camera-11 is-located-in Room-232-of-Building-1

Step 4: SE-1 sends a request to SR-1 in order to solicit applicable reasoning rules for modifying the original query statement. In this request, the SE-1 may send related information about invovled facts (i.e., Fact-1 and Fact-2 so far) and SPARQL statement.

Step 5: SR-1 decides which RS can be used. In this example, SR-1 finds that there is a key word “monitors-room-in” appeared in the SPARQL statement, accordingly SR-1 may decide that the following reasoning rule may be applicable since it also has a predicate “monitors-room-in”:

• Rule-1: IF A is-located-in B && B is-managed-under C, THEN A monitors-room-in C

Step 6: SR-1 modifies the original SPARQL statement based on the applicable Rule-1:

SELECT ?device

WHERE {

?device is-a ex:Camera

~~?device monitors-room-in MZ-1~~

?device is-located-in ?room

?room is-managed-under MZ-1

}

As an optional step, SE-1 may decide that whether additional facts should be incorporated into the original IDB due to the modification on the original SPARQL statement. Note that, in Solution 2, those additional facts just refer to existing facts, i.e., they do not refer to inferred facts, which are mainly obtained through the semantic reasoning operations as done Solution 1 (Remember that the major differences between Solution 1 and Soluton 2: Solution 1 is designed to conduct semantic reasoning operations to find inferred facts, which can further augment IDB and query statements never get modified. In comparison, Solution 2 does not conduct semantic reasoning operations, and it only utilizes applicable reasoning rules to modify the query statement). For example, in order to match the newly-added pattern “?room is-managed-under MZ-1” in the modified query statement, SE-1 may decide that MZ definition and room allocation knowledge should be added as additional facts. For example, the following Fact-3 is one piece of MZ definition about Room-232-of-Building-1:

Fact-3: Room-232-of-Building-1 is-managed-under “MZ-1”

Step 7: SR-1 sends back the modified SPARQL statement to SE-1, as well as an advice about whether additional facts should be used, e.g., the Fact-3 in this case.

Step 8: SE-1 integrates the additional Fact-3 (as suggested by SR-1) with the original IDB (i.e., Fact-1 and Fact-2), and executes the modified SPARQL statement and yields the corresponding result. In this example, there will be a match when executing the modified SPARQL.

Step 9: When completing the processing, SE-1 sends the processing result back to User-1. In this example, due to the utilization of SPARQL statement modification based on applicable reasoning rules, the URI of <Camera-11> is included in the discovery result and sent back to User-1.

### -----------------------End of change 2-------------------------------------------