A Hybrid Graph based Framework for Integrating Information from RDF and Topic Map: A Proposal

Shiladitya Munshi
Department of Information Technology
Meghnad Saha Institute of Technology
Kolkata 700150, India,
WIDiCoReL Research Lab, Golf Green, Kolkata: 700095, India
shiladitya.munshi@yahoo.com

Ayan Chakraborty
Department of Computer Science
Techno India College of Technology
Kolkata 700156, India
achakraborty.tict@gmail.com

Debajyoti Mukhopadhyay
Department of Information Technology
Maharastra Institute of Technology
Pune 411038, India,
WIDiCoReL Research Lab, Golf Green, Kolkata: 700095, India
debajyoti.mukhopadhyay@gmail.com

ABSTRACT
This paper presents a proposal of a new hybrid graph based framework for integrating information within two semantic web information exchange format RDF and Topic Map. The disagreement on common information meta-model in semantic web arena, which is characterized by two mostly used information standards (RDF and Topic Map), is aimed to be hurdled across through the development of an integrated platform. On the background of limitations of the previously proposed solutions which address the issues of interoperability between RDF and Topic Map, we propose a novel hybrid graph based information integration platform for semantic web which can efficiently address the concerns of RDF and Topic Map interoperability. The hybrid nature of the proposed graph based model is characterized by the integration of equivalent semantic relations in a hyper graph - graph data structure framework. Critical theoretical aspects of this model are discussed with respect to the requirements and the methodologies.

Categories and Subject Descriptors
H.3.3 [**Information Search and Retrieval**]**:** Information filtering, Retrieval models.

General Terms
Algorithms, Languages, Management

Keywords
Semantic Web, RDF, Topic Map, Meta-model Mapping, Graph Theory, Hyper Graph.

1. INTRODUCTION
As proposed by Tim Berners-Lee et al [1] semantic web is viewed as the web of information for machines to understand. Instead of considering the web as a collection of linked human-readable data, semantic web or web 3.0 is considered to be a rich collection of machine-comprehensible information [21-26]. Before the days of XML, many a problems of data manipulation have arisen out of the disagreement of common data framework in web 2.0. The same problem has emerged out presently for semantic web or web 3.0, not due to disagreement of common data framework, rather due to disagreement of common information framework. Social in-viabilities of following a single standard information model have been established by simultaneous proposition and usage of many information standards. Resource Description Framework (RDF) and Topic Map are the most prominent and widely used candidates among the many different semantic web information standards. The accessibility, readability and searchability of web information have been considerably limited due to the co-existence of these two types of information frameworks.

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Since last few years, many efforts have been found [2 to 9] which address this problem. Many inter-operable translation mechanisms for semantic web information models have been designed and developed keeping RDF and Topic Map in focus, but none of them were able to overcome the intricacies of information exchange among the said two frameworks completely. Current paper investigates this issue from a different perspective where a direct translation mechanism from one format to other and vice-versa is not considered to be a proper solution to the problem of RDF-Topic Map interoperability. A hybrid graph based framework for information integration which is primarily different from the existing translation processes, is proposed here which would promise completeness and naturalness as well.

On the background of the above discussion, the motivations of the current paper are summarized below.
(i) Constantly growing demand of information integration technologies in semantic web
(ii) Inabilities of current direct cross framework translation processes to meet all the issues of interoperability of RDF and Topic Map; and
(ii) RDF and Topic Map both have an intuitive graph like representation, which could be exploited further for information integration.

Next follows the formal objectives of the present study
(a) To establish the importance of an information integration framework for RDF and Topic Map, which is essentially different from the direct translation mechanisms.
(b) To finalize the requirements for the information integration framework.
(c) To establish hybrid graph data structure as the basic theoretical background for the information integration framework; and finally

(d) To officially propose and discuss the critical theoretical analysis for the hybrid framework.

The detailed structural and semantic analysis of this model is beyond the scope of this proposal. The primary goal of this paper is to theoretically establish the justification of the hybrid graph based information integration model over any kind of RDF to Topic Map or Topic Map to RDF converter. While specific integration mechanisms have been identified as the future research works, the current paper discusses the theoretical aspects of the requirements and approach for this hybrid graph based information integration framework.

Rest of the paper is organized as described next. Section II discusses basic features of RDF and Topic Map with respect to interoperability and mapping issues. While Section III extensively reviews the previous proposals of RDF and Topic Map interoperability, section IV discusses the primary point of differences between direct cross framework translation framework and a hybrid framework for integrating information. Next, section V introduces the concepts of a hybrid graph based information integration framework along with theoretical analysis of the requirements, approach and methodologies for the proposed model. Conclusion of the study and the bibliography are presented at the end.

2. OVERVIEW OF RDF AND TOPIC MAP

The Resource Description Framework (RDF) is a simple metamodel for defining and exchanging information on the semantic web. It was proposed by Tim Berners-Lee and currently has been evolved as a W3C standard [15].

2.1 Resource Description Framework (RDF)

RDF is simple, domain-neutral information metamodel which consists of an unordered set of statements [16]. Each statement is a triple that relates a subject and an object through a predicate. The subject of each statement is a resource which can be thought of just about any-thing identifiable. Every resource either has a single global URI identifier or is a 'blank' resource with unique identity but no identifier at all and which are identified only by the relationships they enter into. While a predicate describes the relationship between the subject and the object and it is also considered to be a resource and allowed to be blank, the object of each statement is either a resource or a literal. Literals are structured objects, not just strings and it may have a language tag, and can be interpreted either as a simple string or as an XML fragment. A literal cannot be the subject of a statement and cannot be interpreted as a typed value.

There are only two concepts to provide basic typing: Property and Type. Type is a resource used as the predicate when stating the type (class) of another resource. Property is the type of all resources that can be used as predicates and Type is of type Property. RDF Schema (RDFS) maintains the notion of typing by introducing the Class concept. The type of every resource must be an instance of Class (that is, a resource of type Class). Class is itself of type Class, giving RDFS an unstratified type model. RDFS recommends that every resource must be the instance of at least one Class, so it introduces Resource, the class of all resources and the class Literal as the class of all literals. Apart from this, RDF framework introduces the concepts of Collection of members and it is characterized by 'Bag', 'Seq' and 'Alt' elements.

2.2 Topic Map

Topic Map [17], currently presented as a standard from ISO, has its roots in concepts of indexes, glossaries and thesauri and it is considered to be a structure for organizing metadata about existing resources.

As suggested in [18], central theme of a Topic Map includes Topic, Associations and Occurrence. A Topic refers to the object or node in the topic map that represents the subject being referred to. Subjects are split into addressable and non-addressable ones. Addressable subjects are reified by specifying a subject address for the topic and non-addressable subjects are reified with a subject identifier which is the address of a subject indicator resource that identifies the actual subject.

There exists a one-to-one relationship between Topics and subjects, with every Topic representing a single subject and every subject being represented by just one Topic. Topics can be categorized according to their type and any given Topic is an instance of zero or more topic types. Topic types in turn are defined as Topics by the standard. All the Topics have three kinds of characteristics: names, occurrences, and roles in associations. A Topic may or may not have a name. Multiple base names are allowed to be assigned for particular Topic and this leads to the concept of scoping.

A Topic may be linked to one or more information resources that are considered to be relevant to the Topic in some way. Such resources are called occurrences of the Topic. The occurrences are generally external to the Topic Map document itself and they are identifiable typically with URIs or HyTime addressing. Occurrences may be of any number of different types and such distinctions are supported in the standard by the concepts of Occurrence Role and Occurrence Role Type. While the Role is simply a mnemonic; the Type is a reference to a Topic which further characterizes the nature of the occurrence's relevance to its subject.

Topic Associations are used to relate two or more Topics as Topic Map is a hyper-graph structure. An association has a Type and a Role and these two features have great significance in Topic Map modelling. Further Topic Map presents the concepts of Facets and Scopes.

The Topic Maps specification offers a framework for specifying subject classification and type generalization relationships, since neither is considered to be a metamodel primitive. Classification employs the type-instance Association Type with the Role Types.

2.3 Critical Comparisons of RDF and Topic Map with respect to Interoperability

According to [7] RDF and Topic Maps are both identity-based standards and the key concept in both is 'Symbols' representing identifiable 'things', which statements can be made about. this 'thing' is identified as 'Resource' in RDF and as 'Subject' in Topic Map. Hence Resources and Subjects have one to one mapping. Similarly the Topics in Topic Map and Nodes in RDF has very close correspondence leaving only one point of difference that while a Topic and a Subject can be used interchangeably, a Node and a Resource cannot.

From the perspective of interoperability, the concern signifies due to the different approach of RDF and Topic Map towards few fundamental metamodel notions. Contrast to Topic Map, an N-array relationship is not supported by RDF. Though an easy formalism is in practice to introduce new Resources in RDF to support Topic Maps' possible N number of association roles, it is not a very clean and meaningful way to establish interoperability or to integrate information. The concern intensifies with the fact that there exists only one form of assertions in RDF (that is statement), whereas Topic Maps have three different kinds of topic characteristics known as names, occurrences, and associations. In spite of the fact that feasible procedures exist in naming a RDF node, qualification of Topic Map occurrence never got its counterpart in RDF.

The issues with Identity make a serious concern about the interoperability. While the Topic Maps deal with concept of 'Subject Address' and 'Subject Identifier' to address the Identity issues, RDF provides no solution at all to the problem. Further, the two metamodels, RDF and Topic Map differ in the process of reification too. In RDF, reified statements need special treatment and hence used rarely whereas reified Topics behave as usual. This peculiarity has a moderate significance in interoperability.

A prominent difference exists in the case of 'Qualification' of the two said standards. Topic Maps use 'Scope' to take care of it but other than 'Language' identifier in 'Literals', RDF has never given any emphasis on the process of 'Qualification'. Moreover, while dealing with 'Types' and 'Subtypes', Topic Maps follow a stratified model but on the contrary RDF follows a unstratified model.

On the basis of the above discussion, it may be concluded that RDF and Topic Map, having superficial similarities in their objectives, implement different concepts for different audience. The two meta-models follow different approach for preserving information; hence the challenge of their interoperability is worth doing an extensive research.

3. REVIEW OF PROPOSALS ON RDF - TOPIC MAP INTEROPERABILITY

In 2001, Moore started a new kind of semantic web research directed towards a data migration within RDF and Topic Map framework and it was considered to be the first step taken towards intended interoperability. Just with the Moore proposal which undertook RDF to TM and TM to RDF translation as well, Stanford proposal was published which concentrated only on TM to RDF translation. The most prominent other proposals to follow were Ogievetsky Proposal (TM to RDF), Garshol Proposal (RDF To TM and TM to RDF both) and Unibo Proposal (RDF To TM and TM to RDF both). A good survey of the existing translation proposal work is already present in [19].

The Moore Proposal [2] described a data translation mechanism through both object level and semantic level mapping between the said two information meta-models; but the superiority of semantic level mapping over object level mapping was established. Both the mappings are not beyond of the boundaries of confusion and incompleteness because of the fact that many a metamodel constructs like Topic Maps scopes, occurrences, subject types or names were not discussed, nor did he discuss the RDF types, containers or reified statements. However, the RDF to TM mapping requires changes to the Topic Maps metamodel, and the reverse mapping fails to realize the nature of RDF assertions, hence this proposal is never implemented. Though the Moore Proposal had little academic or technical values, it was the first effort towards metamodel integration.

In Stanford proposal, Lacher and Decker [3] focused on a TM to RDF translation only where the inabilities of object level mapping towards data preservation was established. The effect of other layers' mapping, like syntactic and semantic mappings, was also discussed. Though there exists an example of the integration by showing a query that spans Topic Map and RDF information, it is quite artificial for proper fit. The user must know the precise boundaries of the lifted topic map, and manually account for the semantic differences in the query. Hence, Lacher and Decker do not achieve true semantic integration of the two meta-models.

The Ogievetsky proposal [4] considered both RDF to TM and TM 2 RDF translation and it scores well with respect to completeness as it covers more-or-less every aspect of XTM syntax. The proposal is based on best possible semantic mapping and hence fails in translating Topic Map association into RDF relation. With a semantic mapping lift, however the problem is managed, the proposal scores very low in naturalness.

Garshol [5 to 8] next proposed a bi-directional translation model for RDF and Topic Map. In this proposal, the object mapping is completely rejected as a probable solution for interoperability. The pure semantic mapping was also not considered due to its incompleteness. The proposal was based on a vocabulary specific mapping that governs a semantic mapping. Garshol proposal works well with respect to naturalness but it is clearly not complete. Some issues really exist with vocabulary generation and its housekeeping, generation of reverse mapping on the fly and some object mapping details like subject locator.

Unibo proposal [9] is mainly based on a hybrid approach with both Semantic and Object mapping which follows Garshol approach for bi directional translation. This proposal is fairly natural, but along with some incompleteness, this has got some serious issues with the round trip translation.

Other than the proposal discussed above, the works presented in [10 to 13] also provide momentum to the cross metamodel data translation research, but all the noted research works are never aimed neither to unify the RDF and Topic Map, nor to develop an upper level model to integrate the information preserved within two models. The model discussed in [14] presents initial works towards integrating the information. The model proposed in the current paper is greatly inspired by the model presented in [14] called as *Braque*. This conceptual metamodel is not complete with respect to functional realization and has greatly motivated the present research to bridge the gap.

4. INFORMATION INTEGRATION VERSUS CROSS MODEL TRANSLATION

The interoperability of RDF and Topic Map could be approached from two completely different perspectives. One being well known cross model translation [2 to 9], and the other being Information Integration [14]. As described in previous section, many proposals have been published which support cross model

translation and comparatively lesser works have been published from Information Integration point of view. The metamodel *Braque* [14], in strict principles, does not deal with RDF and Topic maps alone, but it integrates many meta-models of semantic web and at the same time establishes the superiority of this approach.

Each information metamodel in semantic web has been evolved focusing different perspective for different set of audience; they all have originated inspired by varied set of other models or practices, hence a direct mapping from one metamodel to the other is practically not feasible. Though the difference of syntactical constructs may be bridged, the one to one correspondence of semantic expressiveness between two metamodel is never guaranteed. Critical theoretical analysis of RDF and Topic Map [7] has revealed the major differences in their syntactical, object level and semantic approach. As described in the previous section, all the existing cross model translation mechanisms have failed to maintain completeness and naturalness simultaneously. While the absence of semantic equivalence between RDF and Topic Map leads to incompleteness, the object level distances impart non-naturalness. As suggested in [14], object semantic lifts are often required to to translate RDF to Topic Map or vice versa and hence demand knowledge of target metamodel ontology. The semantic lift also imparts the non-naturalness in the target metamodel as the same feature will have different semantic expressions when semantically lifted. Further, the vocabulary based approach suffers from efficiency and reversibility.

On this background, information integration from RDF and Topic Map provides a cleaner and feasible way of interoperability. The information integration platform is considered to be placed in semantically upper level than the RDF and Topic Map individually. The integration model actually lets semantically poor metamodel RDF to preserve all the semantic features and demands Topic Map semantic features to be viewed generic in nature. Information integration model promises better knowledge creation through generic query system and reversibility is always guaranteed. The RDF integration to the model requires strong semantic beliefs and Topic Map integration demands more flexibility. So a trade-off is required to achieve reasonable amount of interoperability. An information integration model is essentially different from the one to one mapping of RDF and Topic Map in a sense that unnatural and unreliable semantic mappings are avoided and object level distortions can effectively be managed with generic designing.

The information integration model stands generic to the direct metamodel translations. Any of RDF to TM or TM to RDF translation mechanism can (at least) be theoretically possible from the integrated platform. As the literature review suggests that there hardly exist any published work on this direction, incorporating direct metamodel translation into the information integration model would be worth researching. The inabilities of direct mapping of RDF to Topic Map or vice-versa to preserve naturalness and completeness could be covered up by the translation through information integration model as it is more semantically rich and object level tuning liberty is there. Hence the discussion can be concluded with a strong belief that the semantic web vision of providing machine-comprehensible linked data could more be supported by an integrated platform which evolves as more generic model than one to one mapping of information meta-models.

Having justified the importance of an information integration model and its essential difference from the direct metamodel mappings, the next section proposes a novel architecture of hybrid graph based information integration model which is actually a flexible hyper graph - graph data structure to preserve semantics of both RDF and Topic Map.

5. A HYBRID GRAPH BASED FRAMEWORK FOR INFORMATION INTEGRATION

In this section, we propose a hybrid graph based framework for Information Integration concentrating on RDF and Topic Maps. The proposal is an abstract idea of how the information within both the RDF and Topic Map could be integrated at knowledge level through a hybrid data structure of Hyper graph and graph. This framework provides a model which recognizes the importance of both object level and semantic level mapping for an optimal solution. The mapping here involves concepts of RDF, as well as Topic Map and the concepts of the proposed models. The mapping is aimed to incorporate all the semantically equivalent RDF and Topic Map concepts into a common new concept. Where this semantically equivalence is not observed at all, the object level inference could be drawn from both RDF and Topic Map and would be utilized to construct new object level integrity for the proposed model. Hence the objective of the semantic and object level mapping is to integrate both RDF and Topic Map semantics at the knowledge level. The hybrid nature will be manifested by the mapping of semantic correspondence and the integration of object level constructs into a hyper graph connected with graph data structure.

The proposed information integration model views the problem domain rather from a different perspective. In view of the fact that, different information relating to a specific 'thing' may exist in RDF and Topic Map simultaneously, the model under discussion tries to integrate all the information for that specific 'thing' from different RDF and Topic Map sources into an 'integrated framework' so that running queries on that 'integrated platform' will enable better result with respect to search and decision taking. This sets the higher level requirements for the proposed model and opens up the avenues for tuning the lower level criteria.

The current study does not discuss any theory on hyper graph or graph due to space constraint, but aims to present an informal discussion on the potential of the proposed model in preserving RDF and Topic Map information. The possibilities of the proposed model to work efficiently as an information integration model depends on early identification of the requirements and design approach.

5.1 Requirement Analysis

As discussed above, the knowledge level integration of RDF and Topic Map to a new platform is identified as the basic requirement. This knowledge level integration is expected to enable better search and decision making facilities when queried. Hence a formal approach for query processing can be considered as another requirement for the proposed model. A graph based

notations of the instances of the proposed integrated framework will increase its readability and hence to be considered according to its merit.

Proposed model has to integrate the knowledge hidden in RDF and Topic Map frameworks and hence has to support object oriented paradigms. The hybrid model needs to be strongly typed to integrate RDF and Topic Maps. Though Topic Map is not generically strongly typed, but the feature can be incorporated through PSI hence the strongly typed feature will not make the proposed model weak.

Stratification nature of the proposed model is important to be fixed. The unstratified nature of RDF and serializing XML Schema have a strong potential to dictate the nature of the proposed model to be unstratified as well, but the ease and formalized structural relationship of the stratified nature cannot be neglected at the same time. On the background of different related arguments, the proposed model is decided to be following stratified model architecture. Proposed model needs to impose auxiliary semantic constraints to integrate unstratified RDF into itself. The stratification enables the hybrid hyper graph - graph data structure to contain semantically rich information at different levels of knowledge integration.

5.2 Approach and Methodology Analysis

The proposed information integration model allows the instances of the framework to be viewed as a hybrid structure composed of a hyper graph connected with multiple directed labelled graph. The literature review suggests that successful efforts have been done [20, 21] in past to export RDF framework, with all its features, to a directed graph structure, and Topic Map has an inherent hyper graph structure. On this observation, the information integration model can be represented by a hybrid of hyper graph - graph data structure. The simple constraint driven analysis will translate the hyper graph to the graph structure to represent and preserve the knowledge of RDF model. The cost for alteration of stratification nature and constraint application should be analysed in order to address the theoretical background of the proposed model.

5.2.1 Justifications for Graph based Framework

The following discussion justifies the candidature of graph based data structure to represent proposed information integration model. Graphs are mathematical objects which enjoy wide-spread usage for many tasks, which include the visualization and analysis of data for humans, mathematical reasoning, and the implementation as a data structure for developing software. These tasks are relevant in the context of RDF Topic Map data integration as well. Graph can be thought of as a concept of human understanding. Though the evolution of Semantic Web is for machine-comprehensible information, the research efforts on this, demands human understanding of the models also. Hence any graph based data structure is a natural choice. A strong graph theoretical background enables the integration model to exploit graph theory results when the issues of metamodel domain are mapped to graphical domain. The choice of graph based data structure provides an edge to the model to be fit for semantic web applications due to its scalability and path traversal algorithms.

5.2.2 RDF Integration

RDF integration to the proposed structure is inspired by the discussion of [20, 21]. The RDF Graphs are classically defined as set of RDF triplets. The graph interpretation of different RDF constructs exists. URI reference, resources, literals, external variables etc. have their own representations with graph theory, but the representations are never aimed to be fit in a more semantically rich data structure with hyper graph and graph. The unstratified graphical representation needs to be mapped to a stratified one so as to be fit seamlessly as that of Topic Map constructs. The proposed generic hyper graph structure can be associated with a RDF to incorporate the n-array relationships. The classical ways of cross model translation mechanisms has failed to address this problem effectively. Proposed model as represented as a hyper graph has a liberty to incorporate n-array RDF associations which otherwise would be decomposed down to multiple binary associations. The incidence graph of the hyper graph provides the flexibility to represent multiple binary relations also. The graph connected with hyper graph nodes solves the classical RDF semantic shortfall of indirect URI referencing by other expressions.

5.2.3 Topic Map Integration

Topic Map framework inherently supports a hyper graph hence the Topic Map integration would possibly be easy, but the issues related with addressable and non-addressable resources have to be clearly designated. The extra level of indirection within the same strata would be a natural choice for this. The class ontology and type instance of the Topic Map could be integrated in the proposed model through multilevel hyper graph data structure. The different levels of class ontology and type instance should be within a single strata. The scope of Topic Map, which is not present in the RDF concepts, could be expressed with multilevel node structures within the hyper graph. Occurrences in Topic Map could be integrated in the proposed model as a connected graph structures with the nodes of the hyper graph and occurrence roles might be successfully incorporated with edge values in the connected graph. The hybrid nature of the data structure thus gets justified.

The hyper graph structure representation of the information integration is based on the justified mapping between RDF/Topic Map concepts and the hybrid graph constructs. This mapping is essentially different from cross metamodel mapping, as here individual metamodel gets integrated to the proposed framework which has no semantic limitations in the primitive constructs hence low level mapping involving RDF blank nodes, RDF names, Topic name etc. should get done.

The proposed model does not change the source metamodel structure, so the issues with reversibility do not play any role. The hyper graph - graph data structure, due to its scalability, will allow any considerable size of RDF or Topic Map to be integrated seamlessly. Querying within a RDF or Topic Map are mapped to path traversal algorithms while document level querying are mapped to graph matching algorithms. Further the issues related with RDF/Topic Map entailment, minimization, semantic association and clustering would be convoluted to corresponding well known graph theory domain.

Proposed model for integrating information from RDF and Topic Map has been conceptualized as stated above. The model construction with specific integration complexities are not presented here. The discussion presented establishes that the

concept of hyper graph - graph data structure has enough potential for being right candidate for the information integration purpose.

6. FUTURE WORK

The current proposal has a considerable potential for evolving as a computational model of information integration from RDF and Topic Map. Proper justification and conceptualization of the integrated model demands follow up study and experimentations. The hybrid hyper graph - graph data structure discussed informally, must be formally defined and illustrated. The future research must employ concentration on applying path traversal and graph matching algorithm in order to processing queries and other issues. Bi directional changes in stratification within the hybrid structure should have mathematical groundings and the incidence graph generation must follow an elegant way with theoretical basis. The semantic conversion from RDF and Topic Map demands an extensive future study. Graph based theoretical background will fall short to integrate the information if the semantic mappings are not carried out in a proper and cleaner way.

The experimental methodologies need to be identified and fixed for further research to succeed. A detailed planning is necessary to display the effectiveness of the proposed model. The experimentations should be carried out in multiple stages to A) integrate RDF documents B) integrate Topic Map documents C) query on integrated RDF and Topic Map that should produce equivalent result if queried on the individual metamodel and D) query on multiple integrated RDF and Topic Maps that should produce better result than the results if queried on individual metamodel separately.

7. CONCLUSION

Present paper proposes a hybrid hyper graph - graph based model for information integration from RDF and Topic Map sources. The significance of the integrated framework has been discussed on the background of existing cross metamodel translational processes. Critical analysis of RDF and Topic Map is carried from interoperability perspective and the important proposals for such interoperability are reviewed. On the platform laid thus, integrated framework has been proposed. Hyper graph - graph based hybrid data structures has been presented with some critical analysis which are crucial for further study on this.

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