Semantic Web on Scope: A New Architectural Model for the Semantic Web

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Abstract: Problem Statement: Current web contains billions of documents and has many administrative problems and limitations; in addition to that the web content is still accessible only to humans. The solution to these problems is the Semantic Web. The Semantic Web is considered to be the extension for the current web. But there are problems facing the Semantic Web now, such as there is no clear architecture for it, there are four versions created by Tim Berners-Lee, but still up to now there is no agreement for one of these visions nor is there a clear picture for the relation between different layers inside this architecture and the associated technologies. The objectives of this study were to: (i) Identify the weaknesses that existed in the previous architectures and (ii) Reach a new architecture that corrects these weaknesses. **Approach:** This research uses the Qualitative Analysis Approach of Taylor and Renner, presents the four versions of the Semantic Web architecture, describing the function(s) and status of each layer and associated technologies, evaluates them using Gerber evaluation method and determines other design principles needed to modify and adapt this architecture as a step toward an agreement for one Semantic Web architecture. **Results:** The design of a new model for the Semantic Web architecture depends on the idea of previous versions. **Conclusion:** As a step toward a unified architecture for the Semantic Web, our study of the Semantic Web architecture highlighted some weaknesses that existed in the previous architectures, modify, adapt and reach a new architecture that corrects these weaknesses.

Key words: Semantic Web, Software Architecture, XML, RDF, OIL, OWL

INTRODUCTION

Current web contains billions of documents and there are many problems associated with the World Wide Web such as: getting lost in the hyperspace according to the large amount of search results; difficulties of web administration due to the huge number of web pages available on the web today; and the web content being still accessible only to humans. Machines cannot participate in taking a decision. The solution to these problems is the Semantic Web. The Semantic Web is considered to be the extension for the current web. Tim Berners-Lee, the creator of the Semantic Web idea defines the Semantic Web in 2001 as "The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling commuters and people to work in cooperation"[1]. In the same article, Semantic Web is defined as " The Semantic Web will bring structure to the meaningful content of web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users"[1]. Semantic Web is still the main topic of many researches. But there are problems facing the Semantic Web now, such as there is no clear architecture for it; there are four versions created by Tim Berners-Lee, but still up to now there is no agreement for one of these versions nor is there no clear picture for the relation between different layers inside this architecture and the associated technologies. Also there is no clear picture about the implementation of the Semantic Web. All these reasons caused a misunderstanding and confusion to users, developers and researchers in this field.

Related works: The Semantic Web was introduced by Tim Berners-Lee as a conceptual model of a web that makes the contents available read and used by human and intelligently by machines[2]. He introduced the Semantic Web for the first time in one of his speeches in 1998[3]. In 1999, Berners-Lee introduced his vision in

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the IWWW Conference about the future architecture of the web describing the benefits of the Semantic Web[4]. In 2000, he described the Semantic Web architecture in one of his talks in Washington DC and this version was version one[5]. This version was described again in 2001 in the Scientific American Magazine in cooperation with James Hendler and Ora Lassila[1]. The work of Tim Berners-Lee was the spark and the first step toward the Semantic Web. It opens the door for other researchers to work with this architecture. Fensel is one of the main contributors in the Semantic Web field. In 2000, he discussed the Semantic Web and the languages associated with its architecture[6], while in 2002, he introduced with his colleagues the problems and directions facing the layering of the Semantic Web and how Semantic Web languages can be organized in the Semantic Web tower[7]. In the same year, Fensel describes OIL and its relation to OWL and the future capabilities of OWL[8]. Fensel was not the only scientist who made great efforts in this area, but there are many researchers who also participated in this domain, such as Ian Horrocks and Patel-Schneider. In 2005 Ian Horrocks described the different proposals for extending the Semantic Web architecture with rules[9], while working in cooperation with Patel-Schneider in studies focusing on the representation of the Semantic Web and related languages such as OIL and DAML+OIL[10]. Gerber also provides an evaluation method for evaluating the Semantic Web architecture from the software engineering point of view[11]. Ding Ying[12-15], described the functionality and the relation between XML and RDF in the Semantic Web architecture, while the relation between RDF(S) and OWL is described by others like Jeff Z. Pan[16]. Studying these researches and others helps in making a strong foundation for studying different visions of Berners-Lee which are presented in 2000, 2003, 2005 and 2006. But still there is a difficulty as to the fact that there are a lot of details in the Semantic Web which are not written and not mentioned in literature. Gerber faced these problems in his work[17]. Jorge Cardoso agrees with Norman that there is still a long way for the full vision for the Semantic Web and to be a reality[18,19].

MATERIALS AND METHODS

The work inside this paper belongs to the Software Engineering field which is part of the Computer Science and Information systems domain. It uses the Qualitative Analysis Approach of Taylor and Renner

which attempts to put structure to data[20,21]. It focuses on Semantic Web architecture and their associated technologies by giving a complete description of them.

Software architecture: Software Architecture can simply be defined as components grouped together with a description of the interactions and relations between them[22]. Getting the right architecture helps and leads to the success of a software system design and the success of the later stages. There are many architectural styles such as pipes and filters, distributed processes like client-server architecture, layered architecture and other types. Some of these architectural styles are widespread and others are used in specific domains[22]. The complete vision of all of these styles is beyond the scope of this research. The main style related to our work in the Semantic Web is the layered architecture. The layered architecture consists of a number of layers organized hierarchically as in Fig. 1. It can take many shapes like the pyramid shape, circular shape and the tower shape as in the Semantic Web.

Each layer provides a service to its upper layer and serves as a client to the layer below. This kind of architecture depends on the sequence of incremental steps, which means the increasing level of abstraction: if the function of one layer changes, this means that two other layers may be effected[22]. The most famous example for the layered architecture is ISO/OSI (International Standards Organization / Open Systems Interconnected).

In order to understand the Semantic Web architecture for the four versions created by Tim Berners-Lee, the status of each version at that time, which is the time of release of each version, will be presented and discussed, in addition to the description of the functionality and status of each layer in the layered architecture. According to the purpose of this study and for better understanding, each version will denoted by the letter (V) associated by the version number.
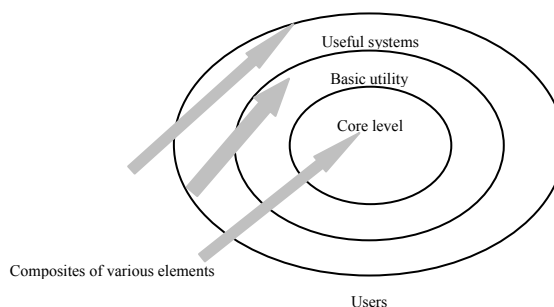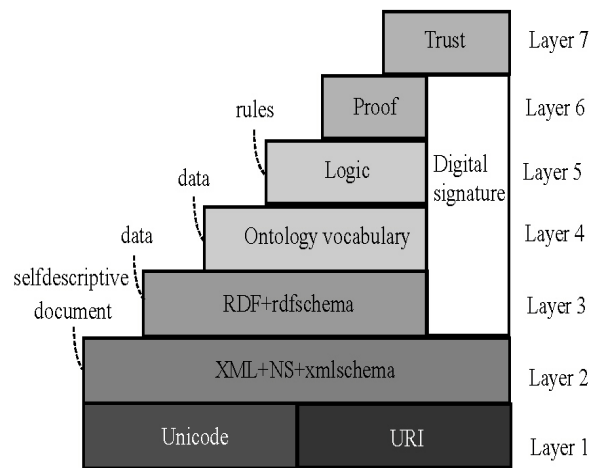

Fig. 1: The Layered Architecture[22]

Fig. 2: Semantic Web Layered Architecture for V1[5]

Architecture of the Semantic Web: Semantic Web layered architecture for the four versions explained in details according to their function(s) and status of each layer and associated technologies.

Version one of the architecture of semantic web layers (V1): This version will be the base version for our study. Here the function(s) and the status of each layer will be described. In other versions the status only will be described unless a function of one layer changes or a modification happens. Version One (V1) consists of seven layers as in Fig. 2. The function and the status of each layer will depend on its location in V1 architecture, the description of the architecture will begin form layer 1.

Layer 1: URI and unicode: Unicode is considered as the universal standard encoding system[23] for computer character representation[24]. Web pages can use a variety of character encoding such as ASCII, Latin-1 or Unicode. Most encoding systems represent only few languages while Unicode represents all languages[25] such as Arabic, English and Chinese. While URI which stands for Uniform Resource Identifier (URI) provides a simple and extensible way for identifying resources.

A resource can be anything that has an identity such as a web site, a document, an image and a person[26].

Function of layer 1: It provides a baseline for representing characters and a unique way for identifying objects in the Semantic Web and between different layers and associated languages in the Semantic Web architecture.

Status of layer 1: Unicode is developed by the Unicode Consortium. The first published Unicode standard was in 1991 and the last one was Unicode 5.1 which was published in April 2008. On the other hand, the uniform resource identifier is specified[27] by the Internet Engineering Task Force (IETF) in 1998[26], which mean that the components of layer 1 were developed before the first architecture of the Semantic Web.

Layer 2: XML, XML schema and namespaces: Layer 2 consists of XML, XML Schema and Namespaces. XML is a language used to represent data in a structural way. It describes what is in the document, not what the documents looks like, while XML Schema provides grammars for legal XML documents[7]. On the other hand, Namespaces allows the combination of different vocabularies.

Function of layers 2: XML, XML Schema and Namespaces, which are the components of layer 2, aim to be a baseline for structuring data on the web but without semantics. It is a mechanism used to describe data in a way that can be understood by the upper layers and can be interoperable.

Status of layer 2: XML is developed by the World Wide Consortium. The first version for XML was XML 1.0 which became a W3C recommendation in 1998, while Namespaces became a W3C recommendation in 1999[28]. On the other hand XML Schema was approved as a W3C recommendation in May 2001 and a second edition of it was published on October 2004[29]. This means that XML and Namespaces were available in 2000 during the time of V1, introduced by Tim Berners-Lee, while XML Schema appears at the same period of time of the article written in the Scientific American in May 2001 by Tim Berners-Lee, James Hendler and Ora' Lassila[1].

Layer 3: RDF and RDF schema: Layer 3 consists of the Resource Description Framework (RDF) and the Resource Description Framework Schema (RDF Schema). RDF is a way for representing, exchanging and reusing of metadata[30,31]. RDF uses URIs to identify web resources and uses a graph model for the purpose of describing the relationship between different resources[24]. RDF Schema is a simple modeling language introducing classes of resources, properties and relations between them[24].

Function of layer 3: The function of layer 3 is to provide metadata to upper technologies placed on the

layers on the top of layer 3, in which that metadata can be exchanged and reused between these technologies or between these technologies and other applications.

Status of layer 3: RDF model and syntax became a W3C recommendation in 1999, while the complete version for RDF was presented in 2004 as a W3C recommendation consisting of six documents: they are RDF/XML syntax specification, RDF vocabulary language, RDF primer, RDF concepts and abstract syntax, RDF semantics and RDF test cases[32]. On the other hand, RDF Schema became a W3C recommendation on 10 February, 2004[33].

Layer 4: Ontology vocabulary: Ontology is considered the backbone for the Semantic Web architecture provides a machine processable semantics and a sharable domain which can facilitate communication between people and different applications.

Function of layer 4: The main function of layer 4 is the provision of semantics which produces a web of meaning[34]. Using ontologies helps machines process meaning and facilitate sharing of information.

Status of layer 4: There are several ontology languages which are related to the Semantic Web. The first ontology language presented was OIL in 2000. Then DAML was developed at the end of 2000 by DARPA. Then DAML+OIL[35] was developed and appeared as a W3C note on 18 December 2001,[36] but unfortunately this language did not become a W3C recommendation. All of the three languages described here are not fully compatible with the architecture of the Semantics Web and at the same time not recommended by the W3C. OWL was the ontology language developed especially to fulfill the needs of the Semantic Web architecture to an ontology language. OWL became a W3C recommendation on 10 February 2004 which means that it was not available as a recommended language for V1 and V2 of Tim Berners-Lee visions for the Semantic Web architecture.

Layer 5: Logic: There is no specific definition for the Logic layer in the Semantic Web, not only the Logic layer, but for Trust and Proof layers. There are attempts to reach to their full meaning, status and functions of these layers, because Tim Berners-Lee propositions and presentations did not describe these layers in details. The Logic layer is placed above the ontology layer. It is supposed that information will be extracted from the web according to this logic.

Function of layer 5: It is supposed to be used as a framework for making new inferences and should have the necessary expressiveness needed for the implementation of the Semantic Web.

Status of layer 5: Up to now, there is no established technology for this layer and is still as a research topic in the World Wide Web Consortium.

Layer 6: Proof: Proof is the layer placed above the Logic layer. It is assumed to be a language used in a manner that describes for agents why they should believe the results. This will be a useful Semantic Web service.

Function of layer 6: Will be used for checking the validity of specific statement.

Status of layer 6: The proof concept is still under research. There is no established technology for this layer.

Layer 7: Trust: A lot of efforts have been exerted to reach the trusted web, but this is very complicated and difficult task and has not become a reality. Trust has many meanings in the Semantic Web. Trust is the final layer in the Semantic Web architecture. It depends on the source of information as well as the policies available on the information source which can prevent unwanted applications or user from access to these sources. For example, who is allowed to see my medical records? Can my doctor see this information[37]? It depends on the policies available on the information source and the doctor privilege. Web of trust can be found if each user trusts a small number of other users[38]. Confidence will come from the trust between parities[39].

Function of layer 7: It is supposed to provide a mechanism for trust and confidence between information sources and parities.

Status of layer 7: There is not much written about this layer nor is there a technology recommended by the W3C to perform this task. There is still need for researches in this area.

The vertical layer: Digital signature: Digital Signature is the only vertical layer in the Semantic Web architecture V1. It begins from layer 3 and ends at layer 6. Digital Signature is a step towards a web of trust. By using of XML digital signature, any digital information can be signed[40]. There are specific elements in XML syntax used for this process such as SignedInfo, Reference and DigestValue.
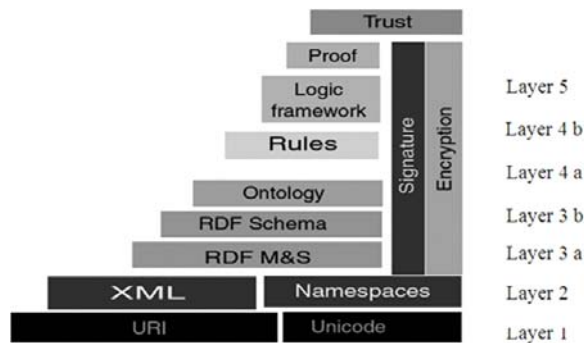
Fig. 3: Semantic Web Layered Architecture for V2[34]

Function of the digital signature: XML Signature can be applied to the content of resources and, by this way; every resource can be identified[41].

Status of the digital signature: XML Digital Signature became a recommendation by the W3C in 12 February 2002[41]; a second edition was presented on 10 June, 2008[41]. The Digital Signature is the result for the cooperative work between the W3C and the IETF.

There is a relation between Logic, Trust and Proof layers. Have we asked ourselves before how we can believe what the computer is saying? In the Semantic Web future proposal there should be logical operations done by some of information processors to make sure of the information given, explaining to the human master if s/he asked, how they came to the particular conclusion they reached. Once the proof has been carried out, it can be sent to other agents to consume time and processing power for checking a valid proof and this we call trust source. If I trust Ali and Ali trusts Ahmed, then I may think to trust Ahmed and, by this way, the web of trust will exist[42]. There is not much written about these three layers, but they are considered as the most difficult challenges facing the Semantic Web.

Version Two of the Architecture of Semantic Web Layers (V2): This version was presented by Tim Berners-Lee in 2003[34] as a modification for the first version. Let's discuss the challenges confronting the Semantic Web architecture (Fig. 3):

Layer 1: Layer 1 still includes URI and Unicode but separated from each other.

Layer 2: XML layer is separated from Namespaces and XML Schema is ignored from the architecture.

Layer 3: Layer 3 in V1 contained RDF and RDF Schema while in this version, layer 3 is separated into two layers, they are RDF M&S and layer above it contains RDF Schema.

Layer 4: This layer was named in V1, Ontology Vocabulary while in V2 was divided into two layers, they are Ontology and above of it a new layer called the Rules layer.

Function of layer 4: Ontology layer used here to provide semantics as V1, while the Rules layer is a general-purpose language that allows query and filtering, such as the Structure Query Language (SQL). It also facilitates mapping between ontologies[43].

Status of layer 4: The available ontology languages at that time were OIL, DAML and DAML+OIL, but none of them was considered as a W3C recommendation. On the other hand, the status of the Rules layer can be described as there are already existing systems for rules such as RuleML[44,45], but these system are not compatible with some of the technologies in the Semantic Web architecture.

Layers 5, 6 and 7 are still the same as V1 unless the name of layer 5 is changed from Logic to Logic framework, which was not explained by Berners-Lee, but the researchers think he changed the layer's name to give wider possibilities for the use of this layer.

Vertical layers: The Signature Layer: remained as it is placed from layer 3 to layer 6, but was called Signature instead of Digital Signature. A new vertical layer is presented from layer 3 to layer 6. This layer was called the Encryption layer.

Function of Vertical layers: Digital Signature is still used to identify resources, while the XML Encryption layer is assumed to be the language for encryption in the Semantic Web for security guarantee. The XML Encryption Working Group aimed to develop a process for encryption and decryption of digital content and also develop XML syntax for encrypted content[46]. As we know that XML is a highly structured data[47], this data can be XML document, XML element or XML element content[48]. By data encryption the internal structure of data is destroyed[47] and the result will be an XML Encryption element containing the cipher data[48].

Status of Vertical layers: The status of this layer can be concluded as follows: the work in XML Encryption started by W3C in 2000[49] and became a W3C recommendation on 10 December 2002[48].
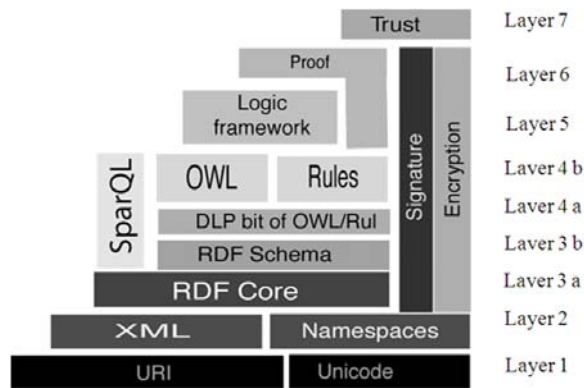
Fig. 4: Semantic Web Layered Architecture V3[50]

Version Three of the Architecture of Semantic Web Layers (V3): Tim Berners-Lee proposed this version in 2005. Figure 4 shows version three of the Semantic Web architecture. Tim Berners-Lee added new technologies such as OWL, SPARQL and bit of OWL/Rul to the architecture. Let's discuss the modification introduced to V2.

Layer 1 and 2: Still presented by the same way as V2.

Layer 3: The name of the first part of the layer which was called 3a in V2 changed from RDF M&S to RDF Core, RDF Schema still as it is in the second part of the layer which was called 3b.

Layer 4: There is no clear description of the place of the new sub-layer DLP bit of OWL/Rul. Is this sub-layer associated with layer 3 which contains the RDF or with layer 4 which contains Rules and OWL? It is more suitable that this layer is attached to layer 4. DLP stands for Description Logic Programs; DLP is a language that is able to integrate knowledge described in Description Logics with Logic Program[51]. After releasing OWL, the attention has turned to design and develop suitable rules languages that can be work with the technologies of the Semantic Web architecture. The modified architecture of the Semantic Web suggests that DLP[52] can be layered on top of RDFS as a common base rule. But this suggestion depends on incorrect assumptions about the semantics of DLP because DLP cannot be placed under OWL in the Semantic Web architecture because it is no longer semantically compatible with OWL[9]. Accordingly, the DLP bit of OWL/Rul layer is omitted from V4 of Tim Berne's Lee visions.

Function of layer 4: OWL is used here to extend RDF Schema and has a great capability of producing ontologies. Rules layer is put in the architecture to allow query and filtering, while DLP is assumed to have the capability of integrating knowledge described in DLs.

Status of layer 4: OWL is included in the Semantic Web architecture as the ontology language recommended by the W3C in 2004 and compatible with RDF and RDF Schema, while Rules are still as it is in V2, but became a separate layer next to OWL not above it. Another rule language called SWRL was submitted to the W3C and aims to combine OWL and RuleML[53,54]. The DLP bit of OWL/Rul layer is placed under OWL & Rules and above of RDF Schema.

Layers 5, 6, 7 are still the same as V2, unless the Proof layer is placed in layer 5 and 6 instead of layer 6 in V2, to be next to Logic Framework, in addition to an attempt made to create a proof language called PML, which stands for Proof Markup Language[55]. However, this language has not become a W3C recommendation up to now. There is no description in literature about the stretching of the Proof layer and how this can affect the Semantic Web architecture. We think this happens because, in some cases, there is a need to a faster communication between the Logic and the Proof layers, especially in authentication process.

Vertical layers: Signature and Encryption Layers are still as V2, but another vertical layer added to the architecture resides between layer 3b and layer 4b. This new layer is called SPARQL.

Function of vertical layers: SPARQL is a query language for RDF and it can work with OWL, while the Signature and Encryption function is still the same as V2.

Status of layer 4: SPARQL became a W3C recommendation on 15 January, 2008[56]. Sesame is an example of SPARQL engines[57], but still up to now there is no specific recommended engine to be used with SPARQL.

Version four of the architecture of semantic web layers (V4): Tim Berners-Lee introduced this version in July, 2006 at the AAAI Conference[43]. This version is assumed to be eight layers instead of seven layers, if we consider the new layer, which is called User Interface and Application, as a separate layer. Figure 5 shows this version.
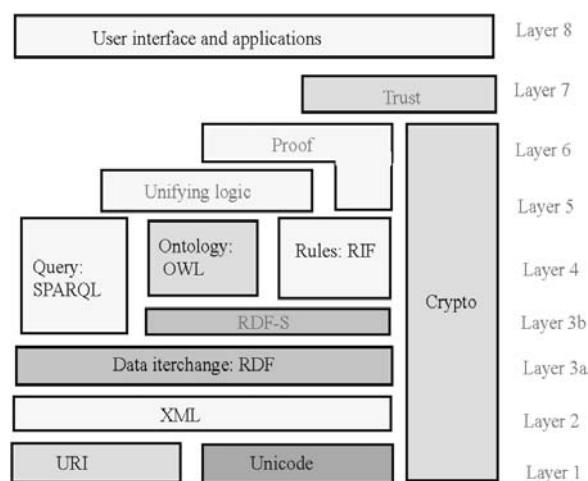
Fig. 5: Semantic Web Layered Architecture V4[43]

Layer 1: Still the same as V3.
Layer 2: Namespaces sub-layer is omitted from the architecture and this layer only now contains XML. This means that XML from the general view is a language that contains inside it other languages and concepts such as Namespaces and XML Schema.
Layer 3: Includes a new concept called Data interchange in addition to RDF. Data interchange is not clear, is it a technology or a new name for this layer. Berners-Lee did not explain it and there is not much in literature about it. RDF Schema still placed above RDF.
Layer 4: Contains OWL ontology and a new language called RIF. This language has not become a recommended language by W3C. It is just a working Drafts published in August, 2008. RIF, which stands for Rule Interchange Format, specifies XML format for rules at intermediate expressive power compatible with RDF and OWL according to what is written by RIF Working Group[58].
Layer 5: Logic Framework name was changed to be Unifying Logic which is not clear, why is this changing done? And how can this affect the job of this layer?
Layer 6: Proof still as V3 resides from layer 5 up to layer 6.
Layer 7: Trust still resides above the Proof layer.
Layer 8: A new layer added above the Trust layer has a name User Interface and Applications which can deploy as a baseline that all user interfaces and applications should satisfy.

Vertical layers: Crypto is a new vertical layer replacing two of vertical layers residing in V3. These layers are Encryption and Digital Signature. The new layer Crypto starts from layer 1 up to layer 6, while Encryption and Digital Signature in V3 start from Layer 3-6. It seems that Crypto layer will do the work of the two layers; Encryption and Digital Signature or maybe it includes them as a container. Also there is not much written in literature about this layer.

Evaluation mechanism for the semantic web architecture: Here the four versions of the Semantic Web architecture evaluated as shown in Table 1, using Gerber's evaluation method to diagnose the weakness of this architecture and explain the possible modification and adaptation can be done to the Semantic Web layered architecture, to reach a generally accepted layered architecture for the Semantic Web.

Table 1: Evaluation for the four versions of the Semantic Web Architecture

Criteria	Conformity
Clearly defined context	**Conform:** The architecture components are languages required for the implementation of the Semantic Web. Note: Agree with Gerber results
Appropriate level of abstraction	**Does not Conform:** The system cannot be viewed as one thing because it consists of different technologies & functional layers Note: Agree with Gerber
Hiding of Implementation details	**Does not Conform:** There is a lot of implementation details in the architecture because of different technologies used as layers in the architecture. Note: Agree with Geber
Clearly defined functional layer	**Partially:** The functions of some layers are clearly known from their names, while others may have technological names which do not explain the functionality clearly.
Appropriate layering including well defined interfaces and dependencies. Also the same case for RDF builds	**Partially:** Most of layers in the Semantic web architecture built on one another according to their functionality, for example XML builds over Unicode and URI because XML syntax depends on both URI and Unicode, Over XML layer depends on XML format which called RDF/XML. But still there are layers do not depend on each other.
Modularity	We disagree with Gerber's definition of modularity. Tim Berners-Lee defines modularity as; if the features can be broken into relatively bound groups having relatively bound features, then this division is a good thing to be made a part of the design[59] and if this is the meaning of modularity, in this case this architecture supports modularity, but here we shall judge according to Gerber's definition. We agree with Gerber that this question answer should be undefined because we have not succeeded so far in reaching the stage of full implementation of the Semantic Web, so we cannot decide whether this can happen or not

Gerber evaluation method depends on a number of criteria that integrated from architecture design and software engineering. These criteria can be described as:

- Clearly defined context: The meaning of this criterion can be the answer of this question. What are the components used in this architecture and why they are collected together?[11]
- Appropriate level of abstraction: Abstraction means that the system can be viewed as one thing or as a whole and this is an advantage, because this architecture does not bother the user with a lot of details[11].
- Hiding of implementation details: The good design is the design that hides the implementations details from the architectural model.
- Clearly defined functional layers: This criterion focuses on the function of each component.
- Appropriate layering including well-defined interfaces and dependencies: The meaning of this criterion can be the answer of this question: Are the layers clearly built on one another and are their relationships and dependencies clear?
- Modularity: By modularity Gerber means that it is possible to change the implementation of a layer as long as interfaces and functionality remain the same[11].

From the evaluation done for the four versions of the Semantic Web architecture, it appears that this architecture needs a modification. But before making any new modification, We think that addition principles of the design in software engineering presented by the creator of the Semantic Web idea should be added to the evaluation criteria such as simplicity, tolerance, decentralization, in addition to modularity that be described clearly by Berners-Lee and is not obvious as a meaning in Gerber's explanation. Let's describe shortly each term from Berners-Lee point of view:

- **Simplicity:** Simplicity here does not mean that the design or the architecture is easy to understand, but means that the using of fewer basic elements to achieve the same power[59].
- **Tolerance:** This means that there is no excuse for a product which contravenes standard[59].
- **Decentralization:** This is one of the main principles when designing a distributed system, because if the system is centralized in one point and this point crashed, this means that the whole system will be crashed and will fail in this case[59].
- **Modularity:** This means that when designing a system, it is a good thing that this system can be

broken into parts that can be grouped with relatively closely bound features. Because if we want to improve the system, this means that we will not destroy the whole system, but only one part or more can be changed and other parts can or cannot participate in these changes; and if changes happen that means that will be too few changes in comparison with the changed part[59].

When design a new architecture for the Semantic Web or modify one of the four versions, the main interest should be in layer functionality not languages and technologies because languages and technologies can be changed fast but the layer function is still the same. There are many examples for languages developed or replaced by other languages such as HTML and XML, also like OIL, DAML + OIL and OWL. For this reason, functionalities of layers should be identified instead of languages syntax and layers should have names reflecting their functionalities, then an explanation for this layer should be provided, through different technologies. By this way the architecture will still provide a clearly defined context and abstraction of functionalities.

RESULTS

A new architectural model for the semantic web: This architecture consists of eleven horizontal layers and one vertical layer. Layers are built one over another taking the same architectural view of OSI/ISO, which is not built as the triangular shape of the before four versions, because there is no description of the use of the triangular shape. The only reason for this shape can be predicted that upper layers can only use part, not all, of the lower layers. But this is not a strong reason for the usage of the triangular shape, the OSI /ISO shape, which has different layers of the same width and length, will be more general and suitable for the Semantic Web. Note that the technology suggested to be used with different layers, are suggested according to the technologies available at the time of writing of this research. Figure 6 shows the new architectural model for the Semantic Web which will be described here.

Layer 1:
The unique & uniform representation mechanism: This layer is responsible for encoding of any character whatever this character was written by any language and at the same time is responsible for uniquely identifying different resources. The technology suitable for the job of encoding is the Unicode and URI that will be suitable for representing and identifying uniquely different resources.
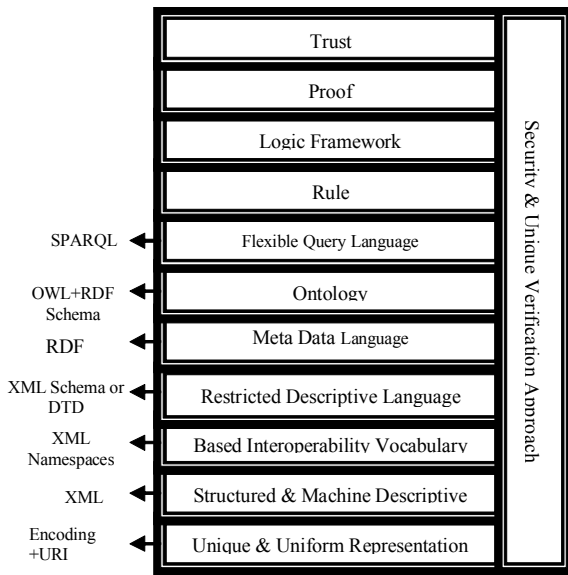
Fig. 6: The new architectural model for the semantic web

Layer 2:
Structured & Machine Descriptive Syntax: This is a language that has the capability of being used as a base syntax for other technologies developed for other upper layers of the Semantic Web architecture. Also this language should be processed by machines to help in the communication of machine together in addition to human which is one of the main reasons for the creation of the Semantic Web idea. Also this layer must have the capability to describe data in a structure way. The suitable language to do this now is the XML.

Layer 3:
The Based Interoperability Vocabularies Mechanism: This is the base that can support mixing of different elements from different vocabularies to do a specific function. So Namespaces can be used in this layer as a mechanism for identifying and distinguishing between different XML elements come from different vocabularies such as Dublin Core and FOAF.

Layer 4:
Restricted Descriptive Language: This is a language used to describe documents written in a Structured & Machine Descriptive Syntax language to be sure that the documents are written correctly according to recommendations. The technology used here can be XML Schema or DTD. This layer introduces the two possibilities because it is very difficult to change most data on the web because DTD is used and according to this reason, DTD should still be used because many documents can still be identified or restricted as regards, using it. However XML Schema is better schema language than DTD. The main importance of

this layer appears when two applications at this level exchange information between each other and it should be a way that assures that the received information is equal to the sent information.

Layer 5:
Meta Data Language: This layer contains the language that provides meaning to the Semantic Web architecture by representing Meta data which is data about data to be accessible and processable by machines which provide integration between different applications. The technology available now that can be used here is RDF.

Layer 6:
Ontology: Ontology can be described as a collection of terms used to describe a specific domain. It provides a mechanism for describing properties and the relation between properties and different resources. Ontology should have the ability to support inference. Some applications may need simple ontologies while others may need ontologies with great capability. So the ontologies that can be used here can be one of two technologies available now, RDF Schema for describing properties and relations of simple ontologies, while OWL used for the more descriptive ontologies. Both ontologies can be used in one application. This depends on the needs and the aim of this ontology.

Layer 7:
A Flexible Query Language: The Semantic Web is a collection of functional layers; these layers presented by different technologies need a query language able to retrieve decentralized information depending on a syntax that can be processed by machines. SPARQL could be the technology available now and recommended by the W3C that can do the job of this layer. Rule, Logic Framework, Proof and Trust layers still have the same name and capability described in V4 of Tim Berners-Lee. But let's describe them shortly.

Layer 8:
Rule layer: This layer aims to support inference, in addition to allow query and filtering. Up to now there is no recommended language for the Rule layer but there is a language called RIF for rules which is still a working draft in the W3C.

Layer 9:
Logic Framework: Logic Framework layer provides the answer for the questions of why this piece of information is taken or appear to the user instead of this piece of information which means that information will be extracted from the web due to this logic. There is no technology specification at present for this layer.

Layer 10:
Proof: The Proof layer is assumed to answer agents about the question of why they should believe the results. At present, there is no technology

recommended by W3C to this layer, but there is an attempt for developing a proof language by the knowledge systems laboratory at Stanford University. This language was called PML. PML tries to address the issue of understanding and trusting results generated by web services. The proposed syntax of PML is considered to be relative to OWL. PML classes are OWL classes and subclasses of owl:Class[55].

Layer 11:
Trust: Trust in the Semantic Web area can be concluded as to be sure that the information provided is valid and there is a degree of confidence in the resource providing this information. At present, there is no recommended technology to be used in this layer.

Vertical layer: **Security & Unique Verification Approach:** In our proposed architecture there is only one vertical layer aiming to provide security and uniquely identifies different resources. This can be done at present using two technologies tied together: they are Encryption and Decryption and Digital Signature. This layer is placed from layer 2 up to the top of the architecture. Both technologies are recommended by the W3C[60].
Evaluation for the new model of the Semantic Web architecture according to Gerber's evaluation method and Berners-Lee criteria is described in Table 2.

Table 2:   Evaluation for the new model of the Semantic Web architecture

Criteria	Conformity
Clearly defined context	**Conform:** The architecture components are layers required for the implementation of the Semantic Web architecture.
Appropriate level of abstraction	**Conform:** The system can be viewed as one thing because it consists of functional layers and do not describe technologies inside the layers
Hiding of implementation details.	**Conform** In this architecture each layer named by its functionality while technologies were not described inside the layers, but annotated for better understanding
Clearly defined functional layer	**Conform:** All layers defined by their functionality.
Appropriate Layering including well defined interfaces and dependencies	**Conform:** Layers in the Semantic Web architecture built on one another according to their functionality. It is an open system.
Modularity	**Conform**
Simplicity	**Conform**: Compared with V2,V3 &V4 find that this architecture has fewer elements .
Tolerance	**Conform**
Decentralization	**Conform**

DISCUSSION

Different versions of the Semantic Web architecture are studied here and evaluated using Gerber evaluation criteria showing the strengths and weaknesses of each version, taking into consideration the vision of Tim Berners-Lee, the creator of the Semantic Web idea. A new modified architectural model of the Semantic Web has been designed by the author according to software engineering principles as a step toward a unified architecture. This new architecture was also evaluated, satisfying the following criteria: Decentralization, tolerance, simplicity, modularity, clearly defined context, hiding of implementation details, clearly defined function layer and provision of an appropriate level of abstraction. This architecture contains fewer layers than Versions 2, 3 and 4 and has more functionality. The main difference between this architecture and others is the dependence on layer description, not only on technologies.

CONCLUSION

Our study of the Semantic Web architecture highlighted some weaknesses of this architecture, modify, adapt and reach a new architecture that corrects these weaknesses that existed in the previous architectures. The main problem facing this work is that Tim Berners-Lee did not discuss in his visions in details, also there are sketchy descriptions by other researchers of these versions. At the same time, there are little written about architecture in literature. In addition to unavailability of technologies or standards at present to some of the main layers in the Semantic Web architecture such as the Logic layer, Proof and Trust. Consequently, this study of Semantic Web needs more than one study, given its multifarious aspects and details with a view to attaining a general viable and operable framework for the Semantic Web.

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