Chapter 1

Introduction

The Web has become a common platform to help a user to search and perform different tasks, such as purchasing electronic items and taking an appointment from medical practitioner. With increased growth of services, it has become difficult for a user to search and select the required services. If a single service is not able to fulfill the complete requirement, it become necessary to combine multiple services to get the desired result. Organizations like, Google, Microsoft, and Amazon have established to deliver their resources as Web services over the Internet. Furthermore, the rapid growth of Cloud computing and Internet of Things (IoT) has increased the demand and re-usability of the Web services (Armbrust et al.), (Atzori, Iera, and Morabito).

Web services may be atomic or composite (Benatallah, Dumas, and Maamar). An atomic service or an elementary service does not depend upon another Web service to fulfill the user requirement, while a composite service integrates other atomic and composite services to offer a value added service to the user. A composite service is represented as a collection of the component services. For example, a composite Web service Travel Planner may aggregate multiple Web services for flight booking, travel insurance, accommodation booking, car rental, etc., which may be executed sequentially or concurrently (Benatallah, Dumas, and Maamar). In practice, organizations use different styles to describe and develop the Web services. Nowadays, there are two types of Web services that are commonly in use: (i) SOAP-based Web services and (ii) RESTful Web services (Pautasso, Zimmermann, and Leymann), (Adamczyk et al.). The first one is based on Web Services Descrip-
tion Language (WSDL) (Christensen et al.) and Simple Object Access Protocol (SOAP) (Gudgin et al.), while the second one follows the REST principles (Fielding). Moreover, end users are able to access these two types of Web services on demand from the cloud service providers, over the Web. This is known as Cloud services. These variants of Web services defines the term Heterogeneous Web services. Heterogeneous services refer to services, that have different functional aspects, such as the interface, the implementation, the data, etc (Neupane et al.). (Lee, Lee, and Wang) have presented SOAP-based Web services, RESTful Web services and Non-Web services as Heterogeneous Web services in the research work.

1.1 Heterogeneous Web services

A brief introduction of Heterogeneous Web services and concepts associated to service discovery, selection and composition are presented as follows.

1. SOAP-based Web services

Web services has been considered as the preferred way to implement the Service Oriented Architecture (SOA) ([Papazoglou et al.], (Papazoglou et al.), (Sheng et al.), (Papazoglou and Van Den Heuvel) and its associated set of objectives. A Web service is a software component designed to support inter-operable application-to-application interactions over the network (Booth et al.). It has a WSDL interface, which can be published and possibly found from Universal Description Discovery and Integration (UDDI) (Bellwood et al.) and accessed through SOAP Protocol. It is important to note that WSDL document can be accessed without the need of UDDI. The Web services architecture (Booth et al.) proposed by W3C has three entities:(i) Web service requester,(ii)Web service Provider, and (iii)Web service Registry, where requester uses the Web services offered by the providers and registry allows these entities to publish and find the Web services. WSDL, SOAP, and UDDI are the three core standards of Web services technologies, which are based on XML language. WSDL is an XML-based interface for describing the Web services. SOAP is an XML-based protocol
for communication between the Web services. While, UDDI is the registry standard, where Web services can be published and found by other entities. More information on Web services has been provided by (Gustavo et al.) and (Newcomer).

II. RESTful Web services

The Resources provided on the Web are increasingly used by applications. REST (REpresentational State Transfer) has gained significant importance, which follows Resource Oriented Architecture (ROA). REST is a set of architectural constraints defined by (Fielding), and these are used to implement RESTful Web services (Pautasso, Zimmermann, and Leymann). REST defines the interaction between a client and a server as the manipulation of states of URI-identified resources with a constrained set of operations, i.e., the HTTP methods. Moreover, hypermedia controls (i.e., links to other resources) allow clients to navigate from one resource to another during their interaction. RESTful Web services is a lightweight compared to the SOAP-based standards. REST is an architectural style, where distributed systems are built on a shared model and have agreement between nouns (resource names as URIs), verbs (HTTP methods used) and content types (usually XML or SOAP).

III. Cloud Services

Cloud services have changed the way computational resources is delivered to customers, by offering computing and storage capacity from remote data centers on demand, i.e., Web services offered as a utility (Drago). A cloud service (Shawish and Salama) is defined as the service, which is made available to the users, on-demand, via the Internet from the cloud provider. All the fundamental services that applied as cloud services are based on the Web services standards. However, creating, offering, selecting services efficiently over the cloud is an open challenge. Cloud computing has been implemented as a major service-oriented paradigm, delivering numerous information technology resources in Web-based services, such as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).
the increased use of Cloud services, service discovery, selection and composition to fulfill the user requirements has become a critical problem related to Cloud services research.

1.1.1 Discovery, Selection and Composition of Heterogeneous Web services

The Web services composition life cycle is proposed by (Sheng et al.), (Moghaddam and Davis), (Shehu, Epiphaniou, and Safdar), (Upadhyaya) as shown in Figure 1.1. My contribution focuses on three main phases of the life cycle: (i) Service Discovery, (ii) Service Selection and (iii) Service Composition for the Heterogeneous Web services.

A service provider publishes the service on a Web service registry, which contains different kinds of service descriptions, i.e., Web Service Description Language (WSDL) or Web Application Description Language (WADL) (Hadley). A service customer queries the registry to retrieve services. Service descriptions specify capabilities of services and usually include inputs, outputs, functional and non-functional description. Figure 1.1 shows the various stages involved in the life cycle of service composition, which are described as follows.

- **Service Discovery**
  Service discovery is a process of searching for services based on user requirements. Typically, a service discovery requires performing the matching operation between the capabilities of services published by the services providers in the service repository and a requester queries. An intermediate entity could be the reasoner in this matchmaking process, which will return the matched result.

- **Service Selection**
  Service selection is the process of selecting (as well as filtering) a suitable service from a pool of functionally equivalent services. Most of the research in service selection is based on Quality of Services (QoS) incorporated in a selection algorithm to achieve an optimized solution. Generally, users express their preferences using QoS parameters. QoS-based techniques help a user to select a service from the results
of functionally equivalent services. Reputation and trust-based mechanisms (Liu, Ngu, and Zeng), (Maximilien and Singh) are also used to filter best services from the service pool.

- **Service Composition**

  Service composition is defined as an aggregation of elementary and composite services. The service composition allows a user to create value added services on top of service description, discovery, and selection activities. Composite services offer reusable capabilities to developers. Service composition provides a seamless access to a variety of complex services to a user. Control flow information, which defines the order of execution of services, is maintained in the form of composition plan (also known as an abstract process). In this process, data flow will be performed, which helps to identify reusable data inputs among services.

### 1.1.2 Exploiting Heterogeneous Web services in Healthcare Domain

An ideal solution is required to make healthcare information inter-operable and easily accessible without any interference of the human-being. By considering this objective, I have
proposed a solution for Web services based Healthcare Information System (HIS) using Semantic Web for the Dentistry domain. My objective of the proposed approach is to provide the platform to the users to search, select and compose healthcare services automatically with easy access and increased level of satisfaction. For the emergency medical situation, effective data management methods and tools are required to move from a web of documents (only understandable by human users) to a web of data, in which information is expressed in a format that can be read and used by machines as well. This would enable to find, share, and integrate information more easily. A prototype has been developed by me using proposed approach for RESTful Web services for Healthcare Recommendation System to help the end user to search, select and compose services using Public data. The exchange and integration of online medical information managed by several healthcare organizations and test centres becomes costly and complex. This motivates to use the cloud computing services and applications in the healthcare domain to alleviate the above problems. A prototype has been developed by me using Cloud services-based approaches for the Healthcare Decision Making System (HDMS) to improve the collaboration among various healthcare organizations and to deal with the challenges, like scalability, availability, throughput, response time, cost effectiveness that are related with Cloud services.

1.2 Motivation

Nowadays, Web services are considered the most demanding mechanism of distributed computing. Moreover, service Discovery and selection are the fundamental processes to search and select composable services based on semantic and non-functional description apart from functional and behavioral aspects to allow rapid creation of new Web services from existing services.

Service discovery, selection and composition are in general, complex tasks, that require considerable effort especially, when vast amounts of services are available. Web service discovery, selection and composition should be performed in an integrated manner due to the strong dependency among these tasks [Rodríguez Mier et al.]. However, researchers have considered the service discovery, selection and composition tasks at individual level. This makes the solution inefficient or partially efficient.
In (Rodriguez Mier et al.), it is clearly identified that, the discovery and composition of Web services should be based on semantic description and should also be QOS-aware. In other words, it states that the composition should consider Web services having the functional, behavioral, semantic, and non-functional properties. Composing Web services by taking into account their conformance from functional, non-functional, behavioral, and semantic aspects together is a challenging issue (Papazoglou and Van Den Heuvel). However, consideration of these aspects together increases the performance of the solution with increased level of user satisfaction and higher degree of automation.

1.3 Objectives

Following objectives have been identified for discovery, selection and composition problem using Heterogeneous Web services.

- To develop framework, approach and prototype for service discovery, selection and composition for SOAP-based Web services using Semantic Web and non-functional characteristics along with sufficient experimental evaluation.

- To develop framework, approach and prototype for service discovery, selection and composition for RESTful Web services using Linked Data principles and non-functional characteristics along with sufficient experimental evaluation.

- To develop framework, approach and prototype for service discovery, selection and composition for Cloud services using Semantic Web and non-functional characteristics along with sufficient experimental evaluation.

1.4 Scope of the Work

The scope of the work for the service discovery, selection and composition problem is as follows.

- To focus on SOAP-based Web services discovery, selection and composition using Integrated approach based Ontology and non-functional characteristics. To evaluate the performance using standard dataset such as Web Service Challenge (WSC). To develop a use case scenario for Healthcare sector.
To focus on RESTful Web services discovery, selection and composition using Link Open Data (LOD) and QoS-based approach. To evaluate the performance with publicly open datasets such as Linked Open Data. To develop a use case scenario for Public data and Healthcare sector.

To focus on Cloud services discovery, selection and composition using Ontology and QoS-based approach. To develop a use-case scenario for Healthcare sector.

1.5 Major Contributions of the Work

The contributions of the work are specified as below.

- **Frameworks and approaches for discovery, selection and composition of Heterogeneous Web services** - The frameworks and approaches for service discovery, selection and composition of Heterogeneous Web services have been proposed, i.e., SOAP-based Web services, RESTful Web services and Cloud services.

- **Prototype Development** - Based on the frameworks and approaches, Prototypes have been developed for Healthcare Information System, Population Information System, Healthcare Recommendation System and Healthcare Decision Making System. Publicly available US census data and healthcare dataset have been used to develop the prototype. Moreover, performance evaluation of these prototypes have been done.

1.6 Organization of Thesis

The rest of the thesis is organized by collection of chapters as below. Chapter 2 covers necessary background information of service discovery, selection and composition for the heterogeneous services, such as SOAP-based Web services, RESTful Web services and Cloud services.

Chapter 3 discusses the literature review of the existing service discovery, selection and composition approaches and solutions for Heterogeneous services, such as SOAP-based Web services, RESTful Web services and Cloud services.
Chapter 4 presents the proposed architecture and approaches for Web service discovery, selection and composition. The related architectures and models are evaluated. Finally, the realization of the architecture is presented in the form of experimental work.

Chapter 5 presents the proposed architecture and approaches for RESTful service discovery, selection and composition. The related architectures and models are evaluated. After that, our architecture, its roles and interactions are presented. Finally, the realization of the architecture is presented in the form of experimental work.

Chapter 6 presents the proposed architecture and approaches for Cloud service discovery, selection and composition. The related architectures and models are evaluated. After that, our architecture, its roles and interactions are presented. Finally, the realization of the architecture is presented in the form of experimental work.

Chapter 7 presents the conclusions with an overview of the contributions. Possible future work is also presented.