Mehran University Research Journal of Engineering and Technology

https://doi.org/10.22581/muet1982.2203.12

2022, 41(3) 120-131

Web services composition in UML: an empirical study

Muhammad Janas Khan [a,*], Wahab Khan [a], Rafiq Ahmad Khan [b], Amad Khan [c], Imdadullah [c]

[a] *Department of Computer Science and Informational Technology, Sarhad University of Science and Informational Technology, Pakistan*

[b] *Software Engineering Research Group, Department of Computer Science and IT, University of Malakand, Pakistan*

[c] *Department of Computing,Abasyn University, Peshawar, Khyber Pakhtunkhwa, Pakistan*

[*] Corresponding author: Muhammad Janas Khan, Email: janaskhan25@yahoo.com

Received: 22 August 2019, Accepted: 25 February 2022, Published: 01 July 2022

K E Y W O R D S

Uniform modelling language

Mashup

Web Services

Web of Things

Internet of Things

A B S T R A C T

Software engineering extending Internet of Things (IoT) to the new extent and in return IoT reshaped the software industry. IoT refers to communicate the real time objects with world wide web. There is a great role of web services in the field of IoT. In the digital world it is the need of the hour to speak with the real time objects. To design such application web of things, provide a common platform for it. This research work analyzes the tools for the modeling of web services, web of things (WoT) and Internet of things. The main focus is to identify the modeling approaches of these technologies through literature review followed by Empirical Study. The study is aimed to improve the quality of the development process in terms of tools and modelling approaches. This research evaluates the tools. A model base approaches compared with the IoT Mashup tool in order to ensure the quality of IoT-based Systems.

1. Introduction

Technology is advancing with the advancement of the software industry [1-3]. Today's software industry is far better than that of 80's and 90's but no one can deny that it was the golden era for technological revolution. The progress of this industry is purely due to its applications to the real time objects [4-5]. The journey of the software industry starts from a small application to the smart rooms and auto-driver cursor even to the smart cities [6]. Billions of devices are connected and controlled by the software. It is rightly said that there is a great contribution of software industry in the development of mankind [7]. Before the start of 21thcentury it was out of the box and no one was even able to imagine that the real time objects will talk to the human and it is possible right now[8-9]. Technological revolution started from the 60's but at that time it was like a dream to communicate and control machines with the instruction provided to them by the mankind. But now the dream comes true and human is able to provide instructions to machine [10].

Web services have a great contribution to this field [11]. It is the primary source to configure that real time objects can communicate with each other in their common language. This provides a base to the IoT. Main concept of the IoT is to have a system of physical object that should be controlled [12], monitored and interfaced to the electronics devices which should communicate

through these interfaces over a connected network [13]. It enables these objects to be kept live on internet. The very first concept becomes popular due to its wide range of applications to the real world.

1.1 Importance of modelling approaches

There is a famous quote "Walk before running". This means modelling before simulation has significance in the development of IoT-based systems [14]. The representation mechanisms are helpful in order to communicate solutions to the problems arises [15]. Different approaches are present to model IoT systems [16], i.e. Agent-based modelling, self-organization, complex network, small-world network etc. System dynamics, differential equation models, discrete event model, disaggregate model, matrix models, individual-based models, object-oriented models, spatial models, modular models, and population dynamic models have great significant effects on the modelling of IoT-based systems. These different modelling approaches help us to get decision about cost and time. These models conceptualize the system in order to construct them. These modelling approaches can test the feasibility, functionality, trade-offs, features, pitfalls, and different sort of analysis etc.

In order to carry out the research, our research questions were as follows.

1. What are the tools used for the modelling of the applications of Internet of Things and Web of Things?
2. How to compare mashup and model-based approaches, for developing a fruitful combination of both these approaches.

The web of things (WoT) is introduced later on with the same intent and to provide support to IoT. IoT is the next generation of internet [10]. As the discussion shows that there must be very complexity in the development of this new technologies. As the technology is not that much mature that one can say that the requirements are fulfilled and now it is relaxed. The problem with the technology is that we can never be 100% sure that the work done is the 100%. It can be changing over night or even a couple of time in a day. Addressing the same issue there are some gaps in the modeling of these complex systems. This paper identifies some tools and techniques for the development of these services. Section 2 of this article presents detailed literature review, section 3 presents the methodology and data collection techniques, and section 4 presents a critical analysis on the literature. Results are provided in section 5 while the final conclusion is made in section 6.

2. Related Work

Basic idea behind web services is that to avail itself on internet using XML based messaging services [11]. XML is broadly used for the encoding of the communication system in web services. The technology is mainly used to enable the human to view the data on web servers and enable this data to flow for the application-to-application communication. The business model of web services has three actors: the service provider, the service broker and the service requester [12]. The service providers publish the web services and register a web service to the service broker. The service requester search and find a web service with the service broker and then use that particular web service for which requester request. All these actors have their own standards which they follow. Web service architecture mechanism is shown in Fig. 1.

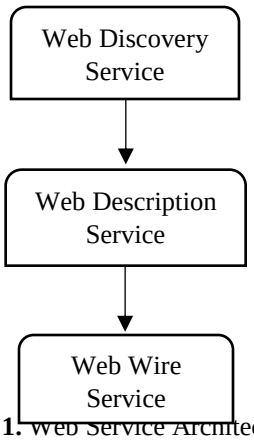

Fig. 1. Web Service Architecture [12]

UML doesn't define the correct semantics for the visualization of the web services. Although UML is a general-purpose modeling language but it can be customizing to different domain specific languages [13]. Web application extension to UML enables us to represent the web services with normal UML class diagrams [17]. The World Wide Web has already customized the UML to their domain specific modeling language. The main issue associated to the web services is that in the maintenance phase. It becomes very difficult in the maintenance to make any changes in the design. This requires a special design modeling language called WebML [18].

Internet of things (IoT) is a new shift to the technology which covers a wide range of area related to the new paradigm [19]. It includes infrastructure, applications, networks architecture and even embedded

systems [20]. Locating and tracking through navigating system is a dominant art of IoT. In the future, new capabilities can be invoked to the real time objects with advancement in IoT. The IoT vision is very wide-e smart environment. IoT aims to empower the things/object/devices with sensory and communication capabilities [21]. US National Intelligence put the IoT in the list of six 'Disruptive civil technologies' with the potential impacts on the US national power [22]. There is huge amount of research available which are working on the progress of IoT in the field of architecture, frameworks, data models and communication protocols [23]. According to [20] there are mainly following three portions where the IoT really trending.

1. Smart things networking
2. Smart entities core function modeling
3. Data presentation and modeling

It is a fact that one can never ignore the importance of the networking in IoT [24-25]. Remove the network then how it is possible to communicate devices with each other. But the interconnectivity of the network devices needs a media, which further requires protocols and tools to transport data among the devices. Fortunately, the Internet Protocol (IP) is widely adopted for the interconnectivity [2]. The development of IPv6 enables the IoT researcher to reuse the same protocol for IoT [27].

Device connection is not the only mean of IoT. This connection or network of devices is just to increase the efficiency of the devices. Interoperability is one of the key pillars of the IoT [28]. If it is lost, there will be nothing to do with IoT. There is diversity in the core functions of the IoT which use different techniques, tools, frameworks, architecture, models and implementations. The real concern of IoT is its deployment [29] but this is not completely dark. There exists a service-oriented architecture where web servers and services keep a good form of the records. Web service architecture (WSA), Service Oriented Architecture (SOA) and Open Grid Service Architecture (OGSA) are the concurrent models from the modeling backlog.

Another most important factor associated with IoT is how the data will be going to be exchange between the interconnected devices. Interoperability doesn't only mean that the device will undergo to communicate but it will also define the procedure for transmitting data. The transmission of data requires specific format and structure. The use of standards at this stage is not advisable but the use of pre-define structure can be good choice for IoT deployment [27, 30]. Semantic approach can be a good option because it consists of not only data, but data and their respective semantic metadata allows the interoperability to communicate all the included entities [28, 31-33]. The engineers tried to engineer a domain specific language for the internet of things [34]. All these domains specific language developer forgot the end user which may be a common person besides a software engineer. UML face the same issue in the field of IoT [30, 35-37] that how to design a language that is easy at the same time for both developers and non-technical people. There is an effort made by [33] to develop a visual domain specific modeling language. In [34] an informal Mashup notation has been used for the modeling of the communication system of IoT which is inspired by the UML. This notation language reuses all the UML models for IoT. Another more formal UML based modeling approach to IoT were given in [35]. In this formal presentation standard UL has been used to explain the dependencies between the elements. Another similar approach is presented in the [36]. But it suggests that standard UML can be used for the modeling of some segments of the IoT and it will not give much detail about how to use it; suggests a handier informal but powerful visual tool for the flow-based modeling of IoT [37].

3. Methodology

There is deep effect of the data collection techniques on the data analysis [38]. This selection is done very carefully. The methodology for this research consists of the literature review, piloting and industrial survey [39] [40]. First the literature was studied critically and identified some tools and techniques from the above literature. From the literature, there is a deep understanding that there are two approaches towards IoT models [41-42]. One is UML-based approach and the other is IoT Mashup tool. After conducting a result-oriented review, a general survey conducted from different organization across Pakistan in order to validate the approaches identified in the literature. The mechanism for questionnaire distribution was quite simple. First a general survey conducted in order to find out the organizations working on web services, IoT and WoT and we found 300 organizations in the first stage. In the second phase some more questions were added to refine the targeted companies and the companies refined to 37. In the third and final phase, the questionnaire is refined and modified according to area of expertise. We have presented the list of companies in Table 1. The research methodology flow is presented Fig. 2.

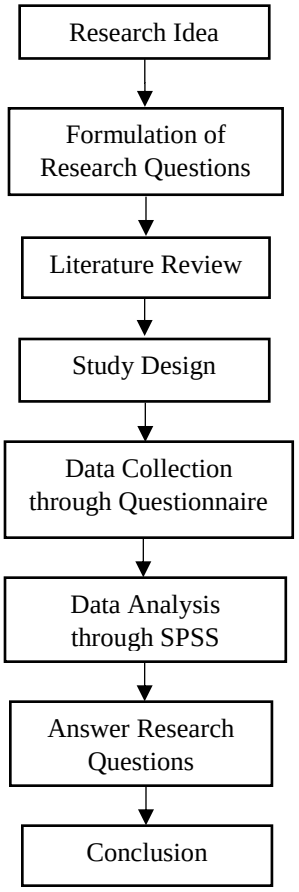

Fig. 2. Research Methodology Flow

Table 1

List of Companies

S. No.	Company Name	Employees	Size	Location
1	Solhut	50+	Medium	Lahore
2	E-Pakistan		Large	Islamabad
3	Fiverivers	200+	Large	Lahore
4	SofTech systems	200+	Large	Lahore
5	PureTech	20+	Small	Peshawar
6	Folio3	200+	Large	Karachi, US, Bulgaria, UK, Canada
7	BitSym	40+	Medium	Islamabad, US
8	10Pearl	500+	Large	Karachi
9	AALOGICS	50+	Large	Karachi
10	Digital Dividend	50+	Large	Karachi
11	Icreativez Technologies	50+	Large	Karachi
12	Inquisitives	250+	Large	Karachi
13	Unique Software Development LLC	250+	Large	Karachi
14	Esipick	250+	Large	Lahore
15	Liquid Technology	10+	Small	Karachi
16	Zablesoft	10+	Small	Lahore
17	Allomate Solutiona	50+	Large	Lahore
18	NorthBay	1000+	Large	Lahore
19	Communication Square	50+	Large	Lahore
20	Erpisto	1000+	Large	Lahore
21	Creative Ideator	50+	Large	Karachi
22	String Services	250+	Large	Islamabad
23	Zillion	50+	Large	Lahore
24	Next Generation Business Solutions	50+	Large	Islamabad
25	Dev House	50+	Large	Gujranwala
26	SDSol Technologies	250	Large	Lahore
27	Digital Dividend	30+	Medium	Karachi
28	Technosoft Solutions	30+	Medium	Lahore
29	DPL	250	Large	Islamabad
30	Datum Brain	10	Small	Lahore
31	Origami Studios	30+	Medium	Lahore
32	Royal Cyber	500+	Large	Karachi
33	Metis Pvt. International	200+	Large	Islamabad
34	BaariSoft	30+	Medium	Rawalpindi
35	Tintash	200+	Large	Lahore
36	Goodcore Software(Pvt) Ltd	200+	Large	Karachi
37	TkXel	700+	Large	Lahore
38	Cygnis Media	50	Large	Lahore
39	Arbisoft	700+	Large	Lahore
40	Square63	80+	Large	Lahore
41	OneByte	36	Medium	Lahore
42	Novatore Solutions	25	Medium	Lahore
43	VeriQual	50	Large	Lahore
44	Dynamologic Solutions	60	Large	Islamabad
45	Codup.io	50	Large	Karachi
46	CodeJunkie	14	Small	Islamabad
47	Code District	7	Small	Lahore
48	Recurship	7	Small	Karachi
49	Centangle Interactive	25	Medium	Islamabad
50	Buzz Interactive	12	Small	Lahore

3.1 Questionnaire distribution

A questionnaire survey is conducted from different software industries across Pakistan. The population size was selected 300 with confidence level of 90%. The margin of error was 11%. The questionnaire distribution among the respondents was calculated through the following formula.

$$\text{Number of respondents' calculation} = \frac{\frac{Z2\times p(1-p)}{e2}}{1+(\frac{z2\times p(1-p)}{e2N})}$$

Where N is population size, e is Margin of error (percentage in decimal form), and z is z-score. According to this formula, the questionnaire was then distributed among 70 respondents. Response percentage was then calculated through the following formula.

$$\text{Response rate} = \frac{\text{Number of responses to survey}}{\text{Number of Survey sent}} \times 100$$

The survey got 50 responses from the industry which is 66.66% response rate. Thus, the results are validated by setting the standard that the response rate should be between 60% and 80%.

4. Data Analysis and Results

This section presents the exclusive evidences for Web Services, WoT and IoT from reviewing the literature and then survey results are also presented through graphs and discussed briefly. Tools and techniques for the development of Web Services, WoT and IoT are described as under.

4. 1 Web services tools

HTTP web technology was originally designed for the human-to-machine communication but later on with the advancement of technology and the inventions of robotics, these web-based technologies are modified to get machine-to-machine communication. Web services are of following two types.

1. Generic web services
2. Specific web services

4.2 Generic web services

These services are offered by the electronic device to another electronic device to make both the devices able to communicate. This make a generic web services model [43]. This communication mechanism is described by the World Wide Web. All the protocols are defined by the World Wide Web.

4.3 Specific web services

These services are described to use the web services for the particular technology [44]. For a particular web service technology, the architecture of the generic web services is modified to get some specific goals like W3C web services [45-46]. There are a lot of web service frameworks available for the web services.

Some basic Web services architectures are specified in the following subsections. There are a number of architectures that define web services with different protocols [47]. These include Java Web Services Development Pack/Glass Fish, Jello Framework, Jersey, .NET Framework, Web Services Interoperability Technology, web services invocation framework, windows communication foundation, WSO2 WSF/PHP, etc. Web service modelling toolkit is an IDE for the Semantic web services which is used with eclipse for modelling of semantic ontology. UML modelling tools are also helpful to model web services applications.

4.3.1 Apache Axis

4.3.1.1 Platform: The platform is Java and C++.

4.3.1.2 Messaging model: It uses client service architecture [48].

4.3.1.3 Specification: It guarantees Web Service Reliable messages, Coordination, Security, Atomic transaction, Addressing.

4.3.1.4 Protocols: It uses Simple Object Access Protocol (SOAP) for the messaging exchange and Web Service Description Language (WSDL) which describe the functionality offered by the web service to a particular module.

4.3.2 Apache Axis 2

4.3.2.1 Platform: The platform is Java

4.3.2.2 Messaging model: It uses client service architecture and support of Asynchronization [49].

4.3.2.3 Specification: It guarantees web service reliable messages, security, atomic transaction, addressing, MTOM, policy and Meta data exchange.

4.3.2.4 Protocols: It uses SOAP1.1 and SOAP1.2 for the messaging exchange, WSDL and WSDL2.0 which describe the functionality offered by the web service to a particular module, message transmission optimization mechanism used for the efficient data transmission, and Representational State Transfer (REST) describe the set of constraints which is used for the creation of web service [50].

4.3.3 Apache CXF

4.3.3.1 Platform: The platform is Java

4.3.3.2 Messaging model: It uses client service architecture and support of Asynchronization [51].

4.3.3.3 Specification: It guarantees web service reliable messaging, secure conversation, atomic transaction, addressing, MTOM, policy and WS-Trust.

4.3.3.4 Protocols: It uses the same Protocols of Apache Axis 2. It uses SOAP1.1 and SOAP1.2 for the messaging exchange, WSDL and WSDL2.0 which describe the functionality offered by the web service to a particular module, message transmission optimization mechanism used for the efficient data transmission, and REST describe the set of constraints which is used for the creation of web service [52].

4.3.4 gSOAP

4.3.4.1 Platform: The platform is C and C++

4.3.4.2 Messaging model: It uses client service architecture, duplex and support of Asynchronization [53-54].

4.3.4.3 Specification: It guarantees Web Service Reliable messages, Security, Atomic transaction, Addressing, MTOM, Policy and Meta data exchange.

4.3.4.4 Protocols: It uses SOAP1.1 and SOAP1.2 for the messaging exchange, WSDL and WSDL2.0 which describe the functionality offered by the web service to a particular module, Message Transmission Optimization Mechanism (MTOM) used for the efficient data transmission, and REST describe the set of constraints which is used for the creation of web service, XML-RPC, JSON, JSON-PRC, XML.

4. 5 Web of things tool

4.5.1 Nutshell

Nutshell is a tool which uses web things model as to integrate things with web especially to HTTP, WebSocket, JSON and JSON-LD [55-56]. This was built to model web of things applications. There are four characteristics of this tool, i.e. modelling protocols, best practices, resources and data models, and semantic extensions.

4.5.2 Paraimpu

It provides a platform to envision and develop a social platform for WoT [57-58]. It defines the model and abstraction with a huge number of objects, data connection flow management and definition of data.

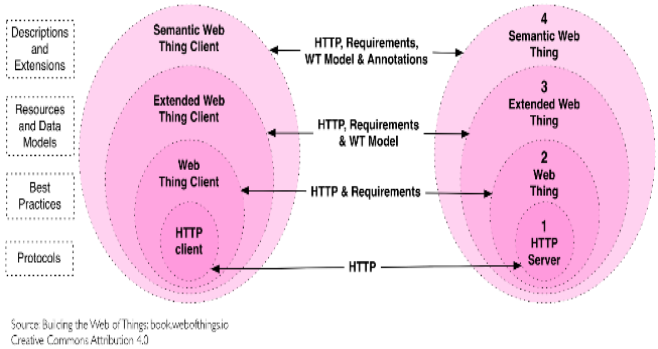

Fig. 3. Nutshell tool characteristics [55]

4.5.3 Internet of things tools

The most famous tools for IoT are discussed in the following subsections.

4.5.4 Arduino

This is an open-source prototyping tool [59-63]. This tool is considered to be the best tool that can develop sense in the computer to sense and control the physical world.

4.5.5 Kinoma

It is Marvell semiconductor hardware prototyping platform [64]. It creates a do-it-yourself (DIY) construction kit to prototype an electronic device. Kinoma studio is an IDE that is been used for the creating IoT projects at runtime.

4.5.6 Papyrus

It is a modelling environment that is used to specify, design and deploy a complex IoT system by using IoT-A which is a lightweight methodology [57, 65].

4.5.7 Clickscript

This tool allows you to write the whole IoT application without writing a single line of code [66-67]. It makes it sure that all the machines and their respective scripts are visible.

4.5.8 WotKit

It is full features IoT platform, which allows the integration and connectivity of devices and sensors to the IoT [68-70]. It enables the user to quickly prototype the solutions of IoT. The IoT is now the reality of the technological world. The emergence of a smart city; millions of smart objects interact and coordinate with each other. Specifically talking about modelling such challenging projects, software engineers and developers faced a lot of difficulties. There is a need of design driven approach which solve such challenges of the developers [71]. DiaSuite is a tool-based methodology

that guides the developer throughout the development process [72-73]. It provides a design language through which the developers can generate high-level application architecture.

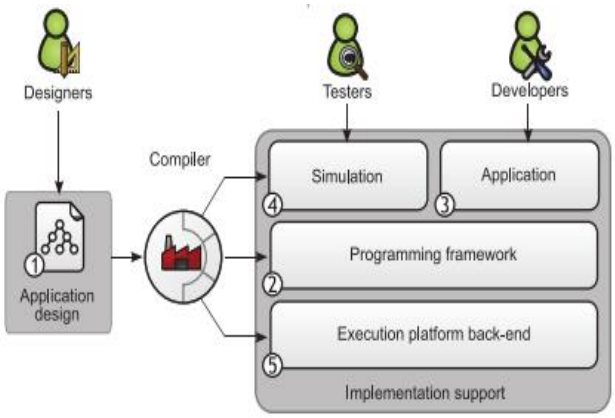

Fig. 4. The DiaSuite tool-based methodology [73]

Besides all these tools and techniques there are still some difficulties in the modelling of IoT systems. As the IoT technology is very heterogeneous so it is very much difficult to develop IoT based system in multiple languages. One of the popular concepts in IoT is mashup [39]. This provides the visual and interactive modelling to the flow of messages.

Model-based approaches are also existing which provide a model view to IoT systems. One of the model-based approaches is the domain specific language ThingML [74-75]. Its motivation is to describe the system on a higher level of abstraction. Typically, this modelling is mainly dependent on UML. The architecture models describe the major roles of class diagrams, activity diagrams, and state machine diagrams.

Model-based approaches have the ability to distinguish between logical objects, components and even the deployment of components [76, 77]. Components have well outlined interfaces and ports, and the matching all the components with notion is found in mashup tools. Mashup tools describe mainly the flow of messages in one diagram. This enables us to describe the architecture by describing the flow of messages through the components. Once the functionality of the component becomes known then it is easy to describe the flow through it. The functionality of the components must be described by the model-based approach. Thus, we are comparing mashup tool with model-based approach in the following section.

5. Comparing mode-based approach with mashup tools

Let's talk about UML modelling approach. There is a wide set of modelling techniques and different set of views for modelling an IoT system [78]. So, we can say that model-based approaches have the ability to define the system with different views by dividing the system into different layers and approaches. And mashup tool defines the message flow which in turn realises the architecture of the system.

As mashup tool defines the flow of messages, and this flow can easily be defined in model-based approach, i.e. activity diagram. In activity diagram we have different approaches towards the modelling that may be synchronous or Asynchronous. But in mashup tool, only synchronous tools can exchange. In this regard we asked a close-ended question from different software experts. The question was 'What is the main purpose of IoT Mashup tool?'. The responses are summarised in Fig. 5.

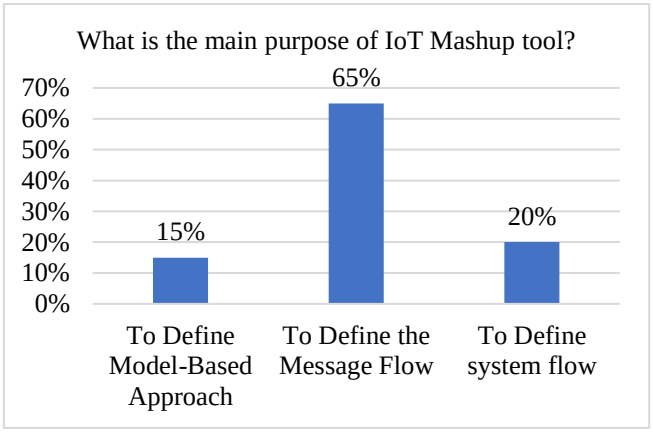

Fig. 5. Purpose of IoT mashup tool

The responses show that the main purpose of the IoT Mashup tool is to define the message flow. 65% of the respondents agreed that IoT mashup tool defines the message flow. 20% respondents confirm that IoT Mashup tool defines the system flow and 15% respondents agreed that IoT mashup tool is helpful in defining the model of the IoT system.

The same question we asked about UML. We asked 'What is the main purpose of UML in IoT?'. The responses are summarised in Fig. 6. Where, the 68% respondents responded that UML provide model-based approaches to the IoT system. 19% respondents responded that UML defines the flow of the system while 13% respondents argue that UML defines the flow of IoT systems.

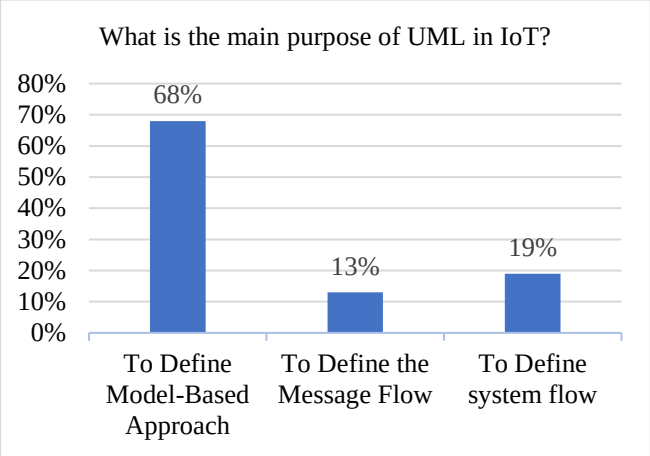

Fig. 6. Main purpose of UML in IoT

Mashup tool consists of black-box entities in Fig. 7 that need to be programmed in some visual programming languages like java. However, model-based approach provides modelling approach to the system. Model-driven development enables us to model the system before the deployment in Fig. 8.

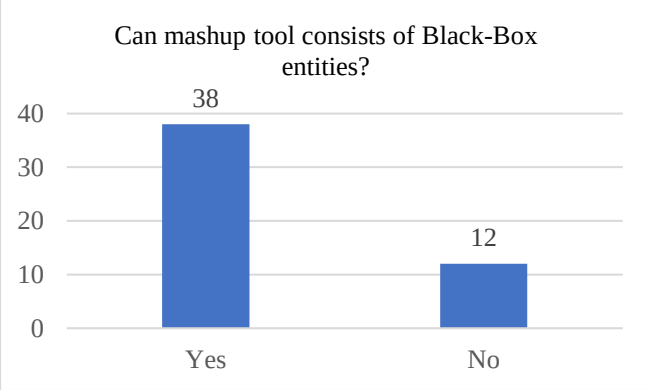

Fig. 7. Mashup tool consists of Black-Box entities

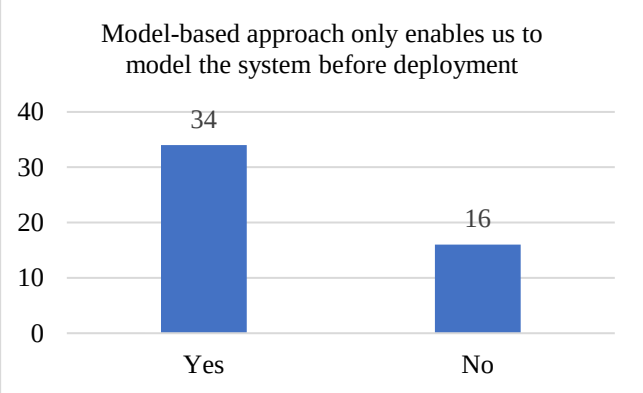

Fig. 8. Enabling to model the system before deployment

Mashup tool is domain specific in Fig. 9, while model-based approach is general purpose modelling language. This means that general purpose modelling languages are more complex than domain specific languages. Model-based approach also enables us to generate code from the model. So, IoT mashup tools are more specific to IoT.

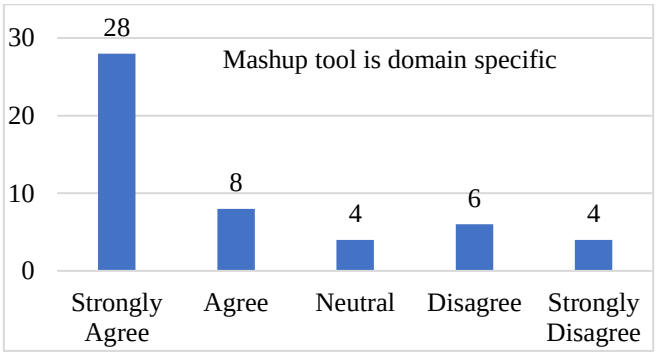

Fig. 9. Mashup tool is domain specific

The responses to this question show that IoT mashup tool is a domain specific modelling language for the IoT. It means that one cannot customize it for other domains. The same question is asked about the UML. The responses are summarised in Fig. 10. The 26 respondents strongly agreed that UML is a general-purpose modelling language. This shows that UML is a general-purpose modelling language. It means that one can customize the UML modelling according to their requirements. We concluded that UML can be customized for IoT-based systems.

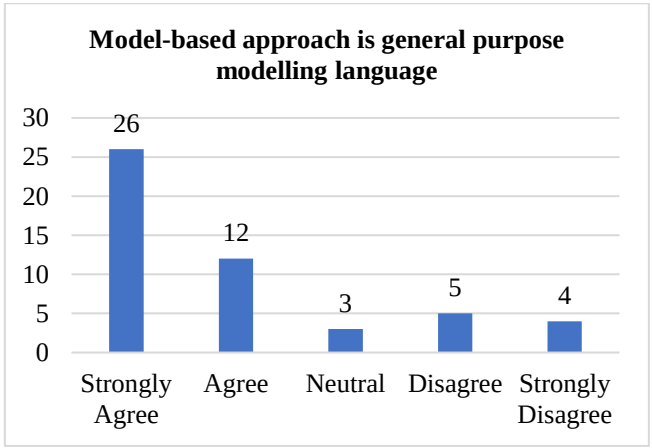

Fig. 10. UML is general purpose modelling language

6. Results

After analysing these approaches, it came to the conclusion that there exist different approaches toward modelling IoT based system. Different approaches have their own benefits to the system. Here it is concluded that one can combine both these approaches in order to get benefits out of it.

The study discussed different tool for web services, web of things and internet of things, which are best for fast prototyping but there is a need of manual models of the system as well. Therefore, both these approaches can go side-by-side to get better results out of it. Model-

based approaches provide different view of the system manually. So, if a system is going to be prototype, it needs to be implemented through different models, which is provided by the UML.

7. Conclusion

This paper presents some tools for modelling web services, web of things and internet of thing. Two approaches are compared. From the whole discussion it came to the conclusion that domain specific modelling languages are benefited for modelling the systems but at the same time there is the need of general-purpose languages as well. This provides the manual implementation to model the system.

8. Future Direction

The limitation of this study is that, this study is not analysing the techniques of modelling. The analysis of techniques is beyond the scope of this study. In the future it is recommended to investigate problems regarding different techniques of modelling web services, web of things, and IoT and provide a combine solution to them.

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