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A Comparative Study of Location Based Services Simulators

Rida Qayyum[1*], Hina Ejaz[2]

[1*]*Department of Computer Science, Government College Women University Sialkot, Pakistan*
[2] *Department of Computer Science, Government College Women University Sialkot, Pakistan*

e-mail: ridaqayyum6@gmail.com[1], hinaejaz299@gmail.com[2]*

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Abstract:- Location-based services are now extremely prevalent due to their massive usage in current and emerging technologies. The use of simulation tools has been gaining popularity in the domain of LBS systems, where researchers take advantage of simulators for evaluating the behavior and performance of new architecture design. This popularity results from the availability of various powerful and sophisticated LBS simulators that are continuously verifying the flexibility of proposed models of LBS research projects. Despite its popularity worldwide, there is still a problem for researchers to choose the best simulator according to their needs and requirements, which provide them accurate results. Furthermore, conducting research on the physical LBS environment for individuals or small educational institutes is very challenging due to the cost involved in setting up location-based services live. Therefore, for selecting an appropriate LBS simulator, it is important to have knowledge of simulators that are currently available along with their features and selection criteria considered for conducting research in a particular type of problems in the LBS system. In the current study, we have presented various simulators that provide a cost-effective way of conducting LBS research projects. This paper compares 10 simulators to help researchers and developers for selecting the most appropriate simulation tool depending on selection criteria. Moreover, a detailed discussion with the recommendation for best practice in LBS simulation tools is also included in this paper, which would surely help new researchers to quickly identify the most suitable simulator according to their research problem.

Keywords: Location-based Services, LBS Simulators, Riverbed Modeler, Network-based Generator, Trace Generator, SUMO, Siafu, GeoLink, GTMobiSim, MobiREAL, GIS, NS3.

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1. Introduction

Recent years have witnessed the emergence of location-based services systems due to the high availability of smartphones, wireless communication, and GPS technologies [1]. Despite the fact, still, there are too many demandable issues that need a meaningful amount of research to be done [2]. For establishing LBS research, it is unattainable for small to large education institutes and many other organizations to maintain a physical LBS System [3]. There is no specification to perform standard experiments, which are repeatable, expandable, and dependable environments using realistic plots and real-world scenarios. Here, all these problems are to use simulators, which could imitate real-life physical situations. It is a process of recreation of a real-world process in a controlled environment [4].

LBS systems strongly believe in the use of simulations to understand complex matters in a short time. These simulators show different kinds of operations by establishing nodes, virtual vehicles, maps, areas of fixed size, mobility traces of humans and automobiles, and many other services that can be designed, making it easier to analyze for LBS [5]. For this purpose, many simulators have been constructed and are being passionately used by researchers to conduct LBS research. These simulators diversify in various fundamental features like programming languages, GUI, licensing, types, focus, extensibility, deployment mode, simulation time, visualization, etc. In literature [2, 10, 14, 22, 26, 28, 32, 36], several research papers already considered some LBS simulators. It is essential for LBS researchers to wisely select a good simulator that provides a user-friendly interface, open-ended in modelling, enable smooth modification, and include appropriate analysis of simulation output and analytical accuracy of results. Thus, simulation technology acceptance will widely spread in the IT community [43, 44]. The advantages provided by simulators over the development of a real LBS system are:

- **Reduced Wages:** Simulation tools do not require any purchase of hardware or proprietary software and nor even maintenance costs. Basically, no capital investment involved. In fact, several simulators are freely available that help in evaluating new protocol design.
- **Repeatable and Controllable:** We can check our experimental set up as much as we need before our desired performance is obtained. It helps the researcher to change input very easily as when needed, which provides better results as an output. Also, it can help in understanding how the system works [6].
- **Environment:** A simulator offers an opportunity to test various scenarios under different workloads. The risk with design or any parameters could be evaluated at an earlier stage through simulation [7]. Hence, a simulation model helps us to gain knowledge about the improvement of the system.

The primary challenge for researchers is to pick the best simulator for their LBS privacy-related research as there are many simulation tools available for specific purposes like Riverbed Modeler Academic Edition for the road network [2], SUMO for vehicular mobility [8], network-based generator for spatiotemporal data [9], and NS3 for user-based authentication protocol [10], etc. Further, to address this problem, we concentrate on existing LBS simulators that are used in the LBS System for many research problems.

In the current study, we have conducted a comparative analysis of various LBS simulators to help researchers in choosing a simulator according to the nature of the issue as there are many diverse simulators present for certain natures of research issues. Moreover, we have presented comprehensive study of these LBS simulators based on diverse criteria and presenting their features and the detailed description which empower new researchers to select a relevant LBS simulator. After comparison, the Riverbed Modeler Academic Edition is suggested according to its attributes and demand in the LBS research community. Moreover, as a general purpose simulator, we suggest Thomas Brinkhoff Network-based Generator of Moving Objects based on its commercial use and visualization in the research and development communities. Hence, these promising solutions help researchers for the right selection of LBS simulators according to their research problem.

Rest of the paper is organized as follows, Section II highlights various simulators used in LBS research. In section III, we have conducted a comparative analysis of popular LBS simulators based on the evaluation criteria. Section IV explains discrete criteria that were used to perform a comparative analysis of LBS simulators. Section V provides the discussion of the comparative analysis and some specific recommendations for best practice in LBS research. Finally, Section VI concludes research work with future directions.

2. LBS Simulators

In order to provide a better understanding of LBS simulators, we have discussed various simulators that are being widely used to conduct LBS research in a simulated environment. Around 10 LBS simulators had been discussed in this section.

2.1 Riverbed Modeler Academic Edition

Riverbed Modeler Academic Edition is the most popular and powerful simulation tool available for the LBS environment. Its old name is OPNET (Optimized Network Engineering Tools). In 1986, it was originally developed at the Massachusetts Institute of Technology (MIT) and used as a commercial tool for modeling and simulation. Riverbed Modeler renders modeling scalable simulation and detailed analysis of a wide range of wired and wireless networks [11]. This is the fastest simulator to analyze and design communication networks. It provides a virtual network environment that models the behaviour of an entire network including its switches, routers, servers, protocols, and individual applications. It model technologies, protocols, and devices, then simulate wired and wireless networks of realistic state and fastly analyze simulation results. Also, evaluate the performance of a proposed network with the help of simulation and transmitting real-time traffic. Riverbed Modeler is an open-source, freely available simulation tool that is too simple to handle and providing a user-friendly interface and customizable presentation of simulation results to the research & development community. In LBS System, the Riverbed Modeler Academic Edition 17.5 widely used for performance modeling and evaluation of proposed techniques in local and wide-area networks [2].

It interpreting output data by constructing complex network topologies, simulate the message sending/receiving, and fixed a region A of size {N km × N km}. Moreover, assign n ×n nodes as sensitive or ordinary locations for simulating the LBS environment [12]. Figure 1 demonstrated the overview of Riverbed Modeler Academic Edition.

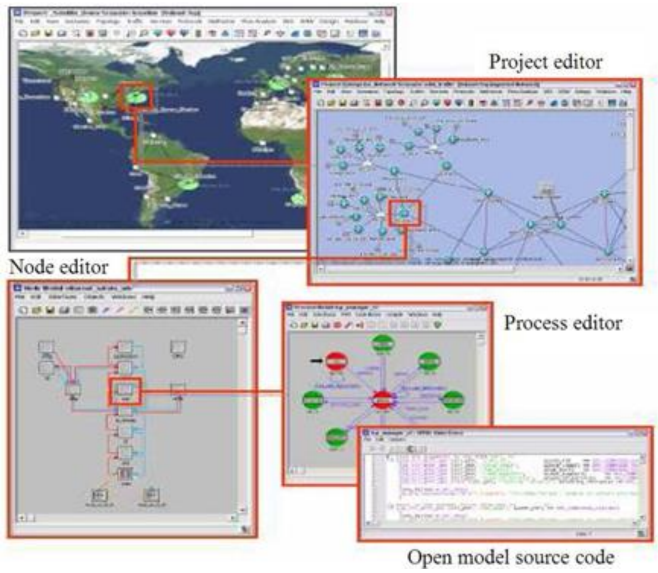

Figure 1. Overview of Riverbed Modeler Academic Edition

2.2 Network-based Generator of Moving Objects

Network-based Generator was developed by Thomas Brinkoff in 1999 for generating moving objects applying a real road network. This generator combines absolute data from the actual road network with user-defined parameters and produces the data. This is one of the few generators that allow the visualization of the data and the road network [13]. This generator was developed in Java and available as a Java applet. Network-based generator control by parameters, configuration file, and open-source Java classes. The graphical user interface of the generator helps in the parameter's setting, the visualization of the network of the created objects [15]. We can specify various features like maximum speed, maximum capacity of a road in it and simulate real-life scenarios like bad weather, building construction on roads, etc. Moreover, we can also add external objects or rectangles wherever we want [14]. For the evaluation of spatiotemporal data, the network-based generator of moving objects was designed. The moving objects follow roads, railways, rivers, channels, pedestrians, migration of living objects. Simple text files specified the network which is used by the generator. For evaluation of the proposed solution in the LBS system, Network-based Generator of Moving Objects is broadly used to set up the moving objects [16]. The generator uses a road map of the Oldenburg County of region area of 23.57km × 26.92km, a city in Germany as the input, and it uses the default setting of the generator for changing the speed of moving objects. Figure 2, shows the global view of the map of Oldenburg with the footprints of mobile users. In our opinion, this generator is the best Spatio-temporal data generator out there.

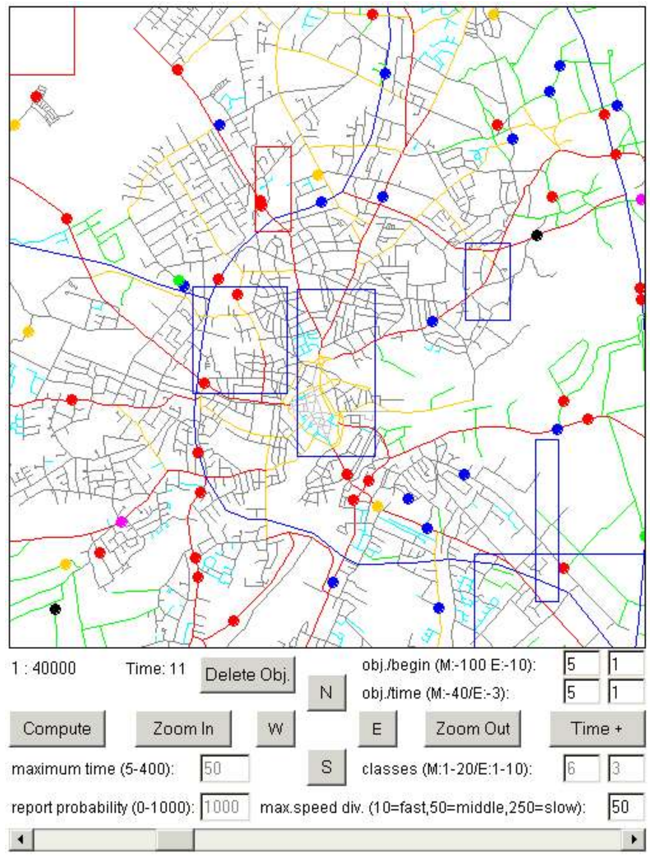

Figure 2. Graphical User Interface of Network-based Generator

2.3 SUMO (Simulation of Urban Mobility)

SUMO is designed as a road traffic simulation for vehicular mobility to deal with a very large number of nodes in road networks. In 1998, it was developed by the German Aerospace Centre and written in object-oriented programming C++, Java, and Python. It has many fundamental features, consisting of single-vehicle routing, collision-free vehicle movement, multi-lane streets with changing of lanes, right-of-way rules based on the junction, an openGL graphical user interface (GUI), and dynamic routing. It's an open-source freely available, highly portable simulation tool that integrates with openstreetmap.org [17] and target map to simulate traffic with a large number of the map of the globe for better understanding. SUMO incorporates helping tools, which handle tasks such as finding the route, visualization, network import, and emission calculation. Also, it provides discrete APIs to remotely control the simulation and it can be increased by custom models. SUMO is just not a traffic simulator, its package contains a set of applications that require a road network and demand for traffic to prepare and perform traffic simulation [8] as depicted in Figure 3. In the LBS environment, SUMO can verify the importance of the proposed model by adopting real-world mobile vehicle traces and managing a large number of streets. To simulate vehicular traffic in the real-world environment, the region map of Northwest Atlanta having information about street nature, the number of lanes, speed constraints could be carried by SUMO from the geo-data origin and evaluate the recommended mechanism using SUMO simulator with real map Northwest Atlanta region. We can perform manipulation by covering a large scale area of {N km × N km} and over 10,000 moving vehicles at fluctuating speeds. We use and extend the SUMO simulator to generate feasible mobility traces for e-vehicles [18].

Figure 3. Graphical User Interface of SUMO

2.4 Trace Generator

The Trace Generator was developed to model moving vehicles on roads for large scale computing industry and to trigger requests from the simulation using the detailed location information. For this purpose, it uses real-world traffic data collected in the USGS [19] format from the National Mapping Department and uses a transportation layer of 1:24K Digital Line Graphs (DLGs) as road data [29]. For input, using Global Mapper Software to translate the maps into Scalable Vector Graphic format and retrieve different types of routes from the original track, grade 1 (expressway), grade 2 (armorial path), and grade 3 (collector). The generator measures the overall number of cars in various road groups using actual vehicular traffic records [30]. The total number of vehicles in a given class of roads is proportionate to the total road length, which is inversely proportional to the average speed of the vehicles in the class of roads. After deciding the number of vehicles along-route type, they are shifted into the graph, and simulation is begun where cars travel through the roads and select other highways as they exit. The simulator aims to ensure that the fraction of the cars is constant overtime on each type of road. The cars at each joint adjust their speeds according to a normal circulation whose parameters already input to the trace generator [31]. It used a map from the Chamblee region of the state of Georgia in the USA to generate the trace used in order to evaluate the proposed solution in the LBS environment. The map loaded into the trace generator will be shown in Figure 4. The area of the map is 160 km^2. As per road frequency, the 1st grade is 7.3% of overall highways, while the 2nd and 3rd grade highways are 5.4% and 87.3%, respectively [32]. Throughout the simulation, each car produces a variety of messages.

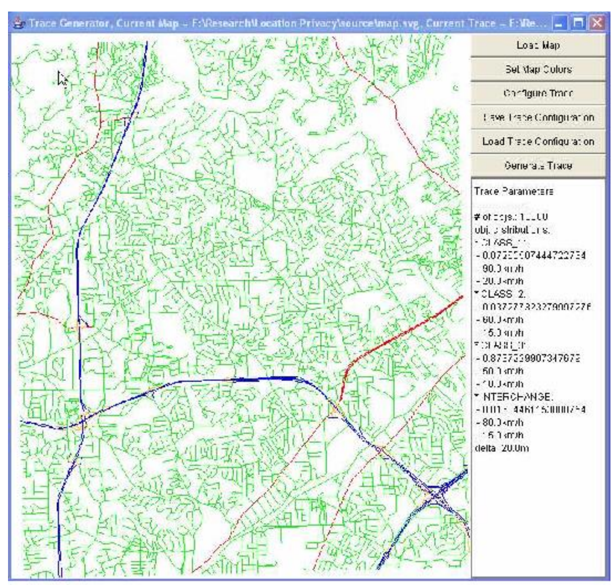

Figure 4. Graphical User Interface of Trace Generator

2.5 MobiREAL

MobiREAL is an innovative network simulator that was developed in C++ object oriented language. It is used for simulating humans and automobile's mobility and facilitates them to change their behavior according to the given application context. Using this simulation tool, we can evaluate the definite performance of infrastructures, network applications, and routing protocols that numerous existing simulators cannot evaluate well. It can efficiently define the mobility of objects with the C++ programming language. Moreover, it follows a rule-based probabilistic model to express the performance of mobile nodes, which is mostly used in cognitive modeling of human behavior [22]. MobiREAL simulator comprises two main parts called MobiREAL behavior simulator which is used to simulate mobile nodes' behavior and MobiREAL network simulator that helps to simulate data transfer between mobile nodes. These two behavior and network simulators are independent programs that systematically exchange significant data over a TCP channel [23]. It also has an animator that visualizes packet propagation, network topologies, and node positions/movements. Figure 5, presents the outcome of the simulation visualized by MobiREAL animator. To check out the robustness of the suggested method in the LBS environment, the network simulator MobiREAL can be employed to simulate the movement of actual users and fake locations [24]. For this purpose, shaped a road network in Kyoto, Japan, and simulates movements of users based on five real trajectories of normal people collected from the route lab. This proposed solution allows us to define how nodes modify their terminal point, routes and speeds/directions according to their positions, environments information obtained from application.

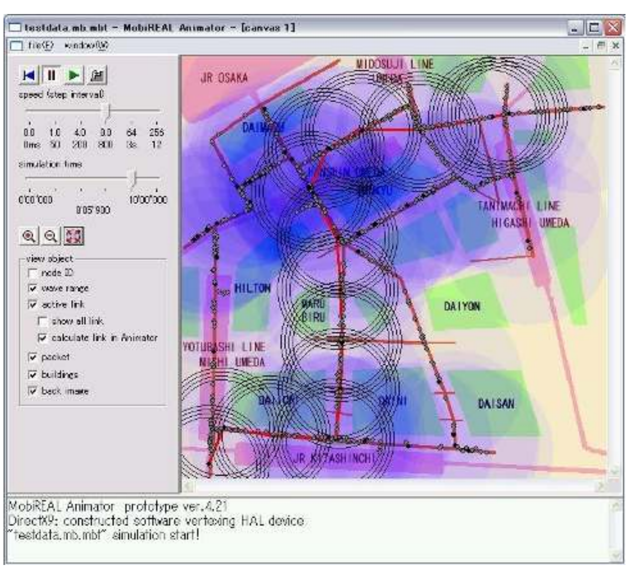

Figure 5. Graphical User Interface of MobiREAL

2.6 GeoLink

GeoLink is an open source simulator provides interactive user interface by showing a map of Digital City Kyoto [25]. In the map, there is a number of links of public places in the map of Kyoto, Kaoru Hiramatsu develops this map and it holds 5400 pages relatively. These public spaces like shopping malls, hospitals, schools, bus stations, restaurants, etc are present in an individual map. Moreover, real-time auditory data is also shown on map that consists of bus chart, traffic updates, weather status, and live video from the animated organizations. More than 300 sensors have already been equipped in Kyoto. It collected traffic data of more than 600 city buses. Every bus delivers its source and destination path and also route data after a few minutes. Such an influential message causes the liveliness of a digital city. As shown in Figure 6, GeoLink can visualize how web pages relate to physical locations distributed throughout the city. GeoLink have both the geographical attributes found in a real city and the online attributes found on the Internet. GIS, VR, social agents and animations are the latest technologies of the time and the city Kyoto was created on these bases. For cost reduction techniques proposed in the LBS system, the GeoLink Kyoto service used in the analysis [26]. This displays many web pages of different spots in city Kyoto and has a database that incorporates the ID, name, position including longitude and latitude, URL, address, category, and a remark of each spot. A geographical database was used to incorporate various information detail. The dynamism of moving objects such as avatars, cars, agents, buses, trains, and helicopters determines a few of the dynamic activities in the cities. Communityware mechanisms are enforced to reassure communication in digital cities.

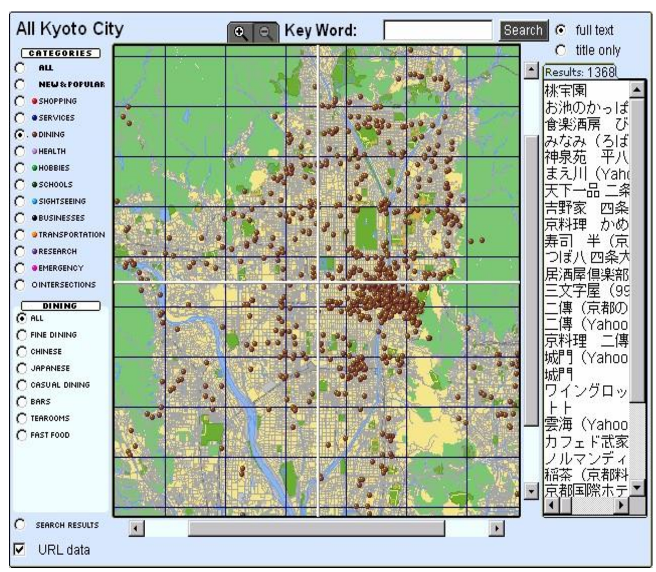

Figure 6. Graphical User Interface of GeoLink Kyoto

2.7 Siafu

Siafu is an open-source simulator based on a Java agent that is used to simulate mobile events in a city. It was originally developed by Miquel Martin working at the NEC European Research Lab within the MobiLife project. The simulator has a graphical interface for displaying and exporting simulation data [27]. The development of agents is manual in Siafu, making it more suited for small, basic situations that can be displayed via an interactive interface. Figure 7 depicts the simulating agents, maps within the scenario. In 2007, Siafu became a commercial, versatile, large-scale context simulator tool that simulated models for agents, places and the context therein. On the other hand, Siafu is interesting in the experimental scenarios proposed in the LBS research work by providing a way to quantify and analyze defined parameters into some environments within each scenario. In order to evaluate the performance and behaviour of new scheme proposed in the LBS System, the researchers and scientists can employ Siafu, the context simulator for generating users' locations by imitating real-life physical situations as it can help in preserving real identity of LBS mobile user from disclosure [28].

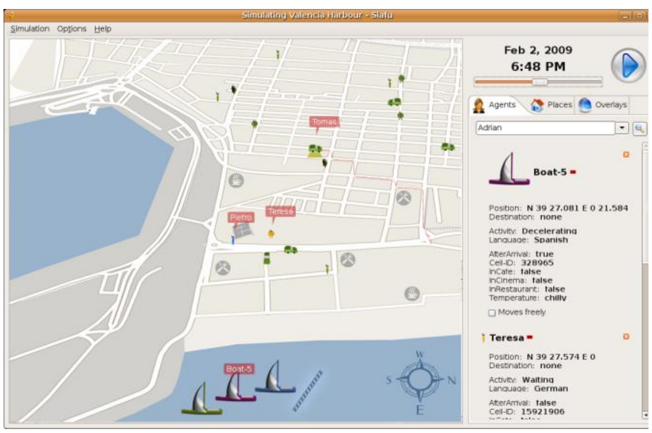

Figure 7. Graphical User Interface of Siafu

2.8 GTMobiSim

GTMobiSim is uniquely build for creating mobility traces and query traces for an immense number of mobile devices traveling over a road network with the uses of maps present at the National Mapping Division of the USGS [19]. It is only used for academic and non-commercial purposes. GT Mobile Simulator driven by an XML configurations files, enables various mobility models on road networks, locations of mobile objects at any time instance, the ability to specify various parameter distributions, and generate query traces. In the LBS System, the performance of proposed privacy protection approaches could be evaluated by using GTMobiSim. To perform the experiment in GT mobile simulator, firstly implement the scheduled approach in a java programming language which is used to develop a trace of moving vehicles on a real- world road network, retrieve from maps accessible at the national mapping division of the Simplified gateway selection (SGS). This simulator uses road networks established with three types of roads i.e. expressway, collector roads, and arterial [20]. There are 3 geographic regions maps that are used for experimentation, Chamblee and Northwest Atlanta, regions of Georgia and San Jose West, region of California to generate indications for designated hour's duration. There is a set of 10,000 cars on the road network that are aimlessly located according to an orderly distribution. Routing is used to direct the cars for random tours. The speed of the cars is appropriated depend on the lane class [21] as demonstrated in Figure 8.

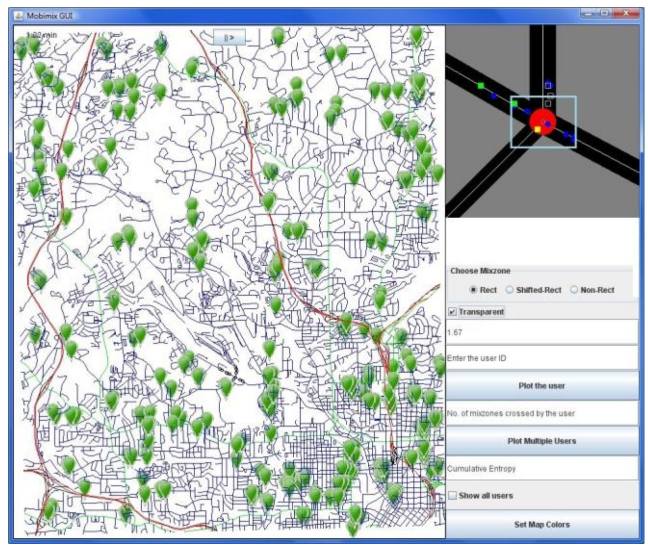

Figure 8. Graphical User Interface of GTMobiSim

2.9 Network Simulator (NS3)

Network Simulator (NS3) is free and open-source software used for small scale computing industry. It was first released in 2008. Tom Henderson supported the growth of NS3 by collaborating with the US National Science Foundation (NSF). NS3 is a standalone simulator licensed under GNU GPLv2. Its latest version was launched in February 2015 as an NS3.22. It is a network simulator that has a simple GUI that helps you to virtually create a network that consists of devices, applications and links as shown in Figure 9. It enables researchers to create network scenarios, design protocol, perform analysis, and model traffic and study the interaction between various network devices [38]. By using NS3 in the LBS system, it is possible to study system behavior in a highly managed environment and analyze how the system works. It has an efficient user-based authentication protocol for the LBS system over road networks. NS3 [39] can used to improve LBS mobile user's authenticated key by establishing protocol that has shorter time manner, shorten wages, minimize packed data loss and ensure privacy protection as compared to existing state-of-the-art network simulators [40].

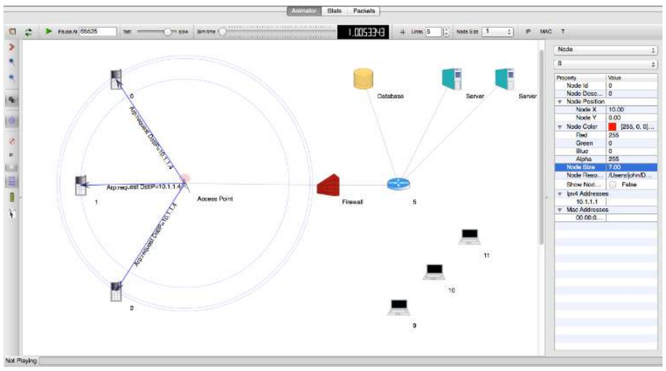

Figure 9. Graphical User Interface of NS3

2.10 Geographical Information Systems (GIS)

Geographical Information Systems (GIS) is uniquely built for providing geographic information services to LBS systems via the internet or mobile-networked environments. It is an open-source information system that is used to manipulate, update, and analyze the spatial and geographic data by presenting them as maps [33]. Both online map services and GIS can be considered important for LBS systems. Its five common components are hardware, software, models, data and people for spatial analysis. As shown in Figure 10. GIS technology combines standard database processes with the exclusive visualization and spatial interpretation advantages that maps offer with these inquiries and statistical analyses [34].

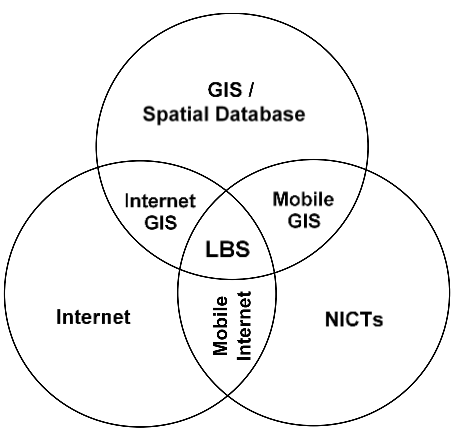

Figure 10. Convergence of GIS technology for LBS

There are further 3 types of GIS as follows:

- **Desktop GIS:** It represents data on desktop and limited to the desktop computer. ArcGIS Desktop (ESRI), envision (Autodesk), MapInfo Professional is the Desktop GIS software [36]. GRASS GIS and Quantum GIS are the free and open-source desktop GIS software. Figure 11 shows the GUI of Geographical Information Systems (GIS). Due to its limitation to desktop PC and not access remotely, it is not very suitable for LBS.
- **Web GIS:** It is a distributed information system that is used to integrate and communicate geographic information over the World Wide Web [35]. Also provide the advantage of global reach, a large number of users, better platform compatibility, easy to use and low cost as averaged by the number of users. Due to diversity nature, distributed data over the internet. Hence, web GIS is suitable for LBS.
- **Mobile GIS:** Mobile GIS is a merged software and hardware structure for access to geospatial data and activities through mobile devices via wired or wireless networks in LBS [37].

GIS address many state of the art research challenges around LBS. For conducting research in LBS domain, researchers can develop a system which uses GIS tools and integrates heat map to preserve the spatial information of mobile user [45]. In order to explore the implications of the emerging geographic information system, researchers can consider a new form of geospatial data for the implementation of advance modeling techniques in LBS.

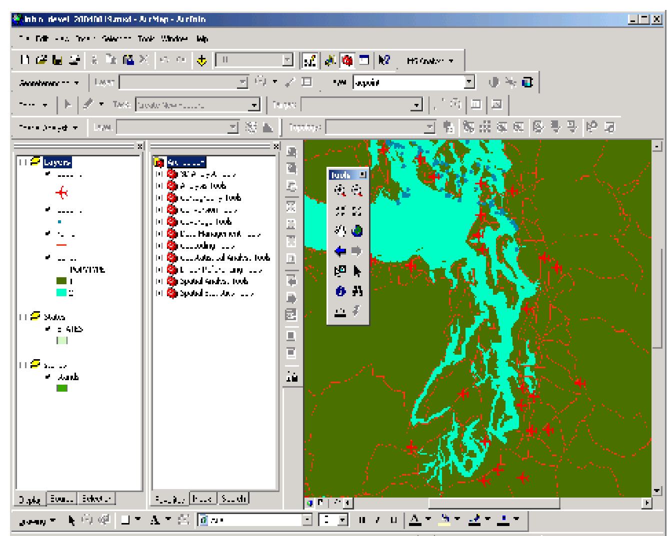

Figure 11. Graphical User Interface of GIS

3. Comparative Analysis of LBS Simulators

In this section, we have made a comparative evaluation of various LBS simulators based on the diverse evaluation criteria. The parameters for comparison were chosen based on many researchers' previous work. Table 1, presents a summary of the analysis. Based on the research objective, this comparative study on LBS simulators enable researchers to choose a simulator according to the nature of the issue as there are numerous simulators geared for specific types of research problems.

Table 1. Comparative Analysis of LBS Simulators

Simulators	**Availability**	**Programming Language**	**Networking**	**GUI**	**Simulation Time**	**Simulation Type**	**Deployment Mode**	**Visualization**	**Focus**	**Map**
Riverbed Modeler	✓	Python	Full	✓	Seconds	Academic	Enterprise	✓	Preserve Identity, Spatiotemporal information	User-defined
Network-based Generator	✓	Java	Full	✓	Minutes	Commercial	Large Scale	✓	Preserve Spatiotemporal data	Real
Trace Generator	✓	Java	Limited	✗	Minutes	Open Source	Large Scale	✗	Preserve Identity & Spatial Information	Real
SUMO	✓	C++, Java, Python	Full	✓	Seconds	Commercial	Enterprise	✓	Preserve Identity & Spatial Information	Real
Siafu	✓	Java	Limited	✓	Minutes	Open Source	Large Scale	✓	Preserve Real Identity	Random
MobiREAL	✗	C++	Full	✓	Seconds	Commercial	Enterprise	✓	Preserve identity & Spatial information	Real
GeoLink	✓	Java	Limited	✗	Seconds	Open Source	Large Scale	✗	Preserve Spatial information	Real
GTMobiSim	✓	XML, java	Full	✓	Seconds	Commercial	Enterprise	✓	Preserve Spatial information	User-defined
GIS	✓	Python, C++, Visual Basic & JS	Full	✓	Seconds	Open Source	Large Scale	✓	Preserve Spatial information	Real
NS3	✓	C++,Python	Full	✓	Seconds	Open Source	Small Scale	✓	User-based authentication	None

4. Evaluation Criteria

In this section, we have introduced several evaluation attributes based on which comparative analysis is performed. Table 1 compares the most popular simulation tools [41, 42] for LBS Systems in terms of Availability, Programming Language, Networking, GUI, Simulation time, Simulation Type, Deployment mode, Visualization, Focus, and Map. The parameters for comparison were adopted based on many researchers' earlier work [2, 10, 11, 14, 16, 18, 20, 26, 28, 32, 38] and are as follows:

Availability: This attribute defines whether the simulator is available for download and use or not. Freely available simulators are those whose source code is under public GNU license and is available for community use. Table 2, contain availability sites of each simulator mentioned in the previous table.

Table 2. Simulation Tools Availability

LBS Simulators	**Availability (sites)**
Riverbed Modeler	Free for academic & non-profit use https://cms-api.riverbed.com/portal/community_home
Network-based Generator	For commercial use https://iapg.jade-hs.de/personen/brinkhoff/generator/
Trace Generator	Free for use https://www.usgs.gov/
SUMO	For commercial use https://www.eclipse.org/sumo/
Siafu	Open Source http://siafusimulator.org/download/
MobiREAL	For commercial use http://www.mobireal.net
GeoLink	Open Source http://geolink.sourceforge.net/
GTMobiSim	For commercial use https://code.google.com/archive/p/gt-mobisim/downloads
GIS	For Free use https://qgis.org/en/site/forusers/download.html
NS3	Open Source https://www.nsnam.org/releases/ns-3-29/download/

Programming Language: This attribute specifies the programming language the simulator used for development. Most LBS research needs improvements to the underlying simulator architecture which has been built through a certain programming language.

Networking: Networking support is crucial to perform simulation for the LBS system. This parameter informs us whether the simulator upholds networking or not. Also, this aspect informs us to what extent the simulation tool supports networking either full, limited or no connectivity.

Graphical User Interface (GUI): The scope of GUI has an important part in the simulation environment and supports the researchers in a way so that they can efficiently execute their simulations in a smooth and productive way. This characteristic confesses whether a simulator grants a GUI or not.

Simulation Time: This aspect expresses researchers how much time a simulator takes to execute the simulation and display the appropriate outcomes. If a simulator takes more time, it portrays that the simulator is ineffective.

Simulation Type: This parameter present whether the simulator is open source which means free for use and anyone can easily access it for research purpose or it is available for only commercial use or just you can use it to fulfil academic goals.

Deployment mode: Current research trend in the LBS system is concerned with the deployment mode of the simulator i.e., enterprise, small and large scale. So, it is important to know the simulator deployment mode to efficiently perform a simulator according to the nature of the research project in the LBS System.

Visualization: Another research trend in the LBS System is to determine the effectiveness of the simulation tool in terms of visualization. Most of the simulators satisfy performance parameters well in respect of the requirement for which they have developed. This attribute tells us which simulator focuses on visualization or not.

Focus: This parameter specifies the purpose and outcome the researchers expect after their implementation in LBS simulators. So, with the uses of these simulators in the LBS system, the researcher can work on the privacy issue of LBS where users can hide their personal data by preserving their identity and spatiotemporal information from the malicious user.

Map: This parameter defines what type of map simulator uses to perform the simulation for the LBS system. Map could be user-defined, real, any random map of areas, or none of the map is used to perform the simulation. This evaluation factor signifies whether the simulator allows researchers to use real-world information obtained from the map or not.

5.Discussion & Recommendation

The current study highlighted the problem faced by researchers and scientists to choose a credible simulator for conducting research in the Location-based services system. Several LBS simulators have been studied for this purpose. In this section, firstly we present a detailed discussion on the comparative analysis of various simulators of LBS based on the evaluation criteria specified in the previous section. Then, describe important recommendations that add scientific rigour to the simulation process for researchers to perform benchmarking experiments on simulators for completing their LBS research tasks. However, the primary findings highlighted in the study are listed down and the brief description of the analysis is described in Table 1.

It is observed from the table that 86% simulators are currently available for conducting research on the LBS system. The availability of these simulation tools enables the researcher to simulate real-life physical situations in a controlled environment. It also observed that almost 67% of simulators were developed in the Java programming language. The second primary programming language is C++ and Python for the development of these simulation tools mentioned in table 1. Only GIS simulator was developed using SQL, Visual Basic, and JavaScript. Moreover, almost 73% of simulators support networking. One adverse consideration is that only 31% of the simulators contribute finite networking for research on LBS. The availability of graphical user interface (GUI) fascinates a higher number of researchers to operate the simulator. It is noticed that almost 76% of simulators have a user-friendly GUI. On the other hand, only 37% of the simulators arrange full to finite GUI for researchers. Regarding the simulation time, approximately 82% of simulators operate in seconds. The simulators that can perform simulation in minutes are Siafu, Trace generator, and Network-based generator for moving objects by Thomas Brinkoff.

In this paper, there are three types of simulators, among these 50% to 60% simulators are open source which means free for use, you don't need to purchase or pay for them. The rest of the simulators are for commercial or academic purposes according to researchers' needs. The aspect of deployment mode is important for researchers to know about the desired results. 45% simulators are working at large scale and enterprise level computing industry and 10% are used at small scale computing industry like NS3. Additionally, LBS system determines the effectiveness of the simulation tool in terms of visualization. It is observed that almost 80% to 83% simulators are excellent at visualization, rest 20% to 17% for example GeoLink and trace generators are not good enough to support visualization. Regarding the focus of simulators, researchers can hide the personal information of LBS user by considering riverbed modeler, network-based generator, GTMobiSim, and many others which are used to preserve identity and spatiotemporal information. On the other hand, NS3 focuses on user-based authentication protocol. The availability of maps plays a fascinating role in LBS research, 60% of the simulators use real-world maps like SUMO and MobiREAL. While 20% of maps are user-defined according to the user's choice and the rest 20% are using just random maps.

Eventually, it is worth to mention about some of special purpose LBS simulation tools. Mobile GIS is the only simulator that enables researchers to observe the performance of the LBS system using real applications with wireless networks that need computationally intensive devices with large display screens. Riverbed Modeler Academic Edition and Thomas Brinkhoff Network-based Generator of Moving Objects are the only simulators that enable researchers and scientists to execute the performance of LBS techniques over road networks. SUMO is the only simulator that supports vehicular mobility for generating traces for humans and automobiles. NS3 is the only simulator that grants research efficient user-based authentication protocol in LBS whereas all simulators discussed in the literature section address privacy-related aspects in the LBS system. We suggest riverbed Modeler academic edition according to its characteristics and demand in the LBS research community. Moreover, as a general purpose simulator, we recommend Thomas Brinkhoff Network-based Generator of Moving Objects based on its commercial use and visualization in the research and development communities. Hence, these promising solutions help researchers for the right selection of LBS simulators according to their research problem. In this paper, we provide some specific recommendations. Specifically, LBS researchers should: (1) choose a good LBS simulator according to the type of problem they are addressing in their research work; (2) Wisely choose statistical approaches in order to reduce the number of simulations and to analyze the simulation results. Adopting these suggestions will help to choose a credible simulator for research on the LBS domain.

6. Conclusion

Simulation technology is increasingly popular among researchers worldwide in recent years. The aim of the research carried out in this paper is to enhance the knowledge of LBS simulators among researchers. This paper discussed LBS simulators' advantages better to understand the real-life physical environment in a short time. This paper's innovative work considers the latest LBS simulators such as Riverbed Modeler Academic Edition, Network-based generator, SUMO, MobiREAL, and GTMobiSim, and many others. All of the 10 LBS simulators have been compared based on ten evaluation criteria: availability, programming language, networking, GUI, simulation time, simulation type, deployment model, visualization, focus, and map. The current research presents detailed discussion and recommendations based on a comparative study, which empowers new researchers to select a relevant LBS simulator. Although there are many LBS simulators available, we can say that picking a suitable simulator according to the type of problem is very important. There are numerous simulation tools geared for certain types of research problems in the LBS system. The current study suggests Riverbed Modeler Academic Edition based on its features and popularity in the LBS research community based on critical analysis. Moreover, as a general-purpose simulator, we suggest Thomas Brink off Network-based Generator of Moving Objects based on its commercial use and visualization in the research and development communities. Hence, these promising solutions help researchers select LBS simulators according to their research problem.

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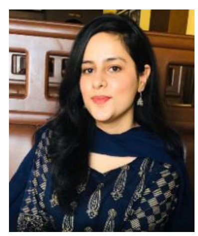
Authors Profile

Rida Qayyum (born September 17, 1996) received BS-Information Technology (BSIT) degree in 2019 from Government College Women University Sialkot, Pakistan. She has awarded with Gold Medal and Roll of Honour for her academic performance in BS-Information Technology from GCWUS and certified as Microsoft Office Specialist. She has many publications in international journals. Her research on Location Based Services Systems, Mobile Cloud Computing, and Big Data has appeared in International Journal of Advanced Research in Computer Science, International Journal of Advanced Computer Science and Applications, International Journal of Computer Engineering in Research Trends, I.J. Modern Education and Computer Science, I.J. Education and Management Engineering and I.J. Wireless and Microwave Technologies. She has served as HPC scientist in High Performance Computing Research Centre.



Hina Ejaz (born March 25, 1997) is currently student of BS in Information Technology (BSIT), Department of Computer Science from Government College Women University, Sialkot. Her research interest including Location based services System, Network Security, Telecommunication System and Computer Communication Network.