LINTAS-BD 1.2: Modeling and simulation traffic of Bandung City using SimEvents MATLAB

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Abstract. Traffic is a very vital medium for various means of land transportation that connects various locations and even large cities. The smooth traffic of a city is one of the performance parameters of the local government. Furthermore, the smooth traffic determines the great development of economic, social, educational and technology. As the increasing level of civilization development and also the population, traffic becomes more congested and becomes a big problem that is very difficult to avoid. In this study, we proposed a traffic simulator system LINTAS-BD 1.2, or commonly called as "LINTAS" which served as a tool to solve traffic congestion problems. Various methods and traffic engineering designs can be simulated first through the LINTAS system, before they are actually implemented on the road. The benefit of the LINTAS is to evaluate and simulate traffic conditions based on the design of a particular method or traffic engineering. Furthermore, through simulations, it can be known and tested analytically about the level of accuracy, efficiency, and effectiveness of the method and design. Through the simulation, the most appropriate traffic management method can be found, so that the problem of traffic congestion can be solved. The model and the design system of LINTAS is the arrangement and integration of various blocks or modules included: roads, traffic light, arrival of vehicles, queues, servers, and various obstacles such as intersections, terminals, markets, branches, etc. These various blocks are then combined into a single unit application as a simulator. The objective of this research is to compile a simulation application (traffic simulator) that can be used as a tool to accurately predict traffic situations, and as a medium for testing traffic engineering. The LINTAS simulator is created using the SimEvents toolbox and runs on the MATLAB-Simulink software. The LINTAS system is compiled based on Mathematics, specifically the Queueing Theory.

1. Introduction
In developing countries, transportation density is increasing every year which is indicated by the continued increase in the number of vehicles that are not balanced with infrastructure expansion. This situation ultimately results in the emergence of global problems namely traffic congestion [1, 2]. Congestion is hampered by traffic flow which is generally caused by two condition, namely the road capacity is limited or the vehicles is too many [3-8]. The general solution for this problem is to increase the capacity of the road or reduce the vehicles number [9]. Unfortunately, the solution is not simple because the increase in road capacity requires enormous costs, complicated land acquisition processes, etc. On the other hand, the vehicles number are not easy to be reduced, since it is related to the policies
and already become the main of community needs which cannot be released directly in daily activities [3, 10, 11].

Traffic congestion is one of the biggest problems in the city of Bandung, which must be prioritized. The Bandung city government is very serious about finding a solution, which is indicated by the implementation of several major projects related to efforts to overcome congestion problems. In fact, looking at the urgency of solving this congestion problem, some of large projects are built simultaneously. Widening the capacity of highways in the city of Bandung is very difficult to do, while the number of vehicles keep increasing. If no resolution is taken, then the problem of congestion in the city of Bandung will be a prolonged dilemma and polemic. Congestion occurs in small cities to large cities, with a high population and busy population. Congestion can also occur because of poor traffic management, and a low level of discipline of traffic users [9-11].

The traffic congestion problems are very important to be solved because they are very detrimental and harming the activities of many people. The disadvantages that arise include loss of time because transportation travel is hampered, waste of fuel, damaged vehicles because of heat, air pollution is increased, stress, emotional road users, etc. [12]. Losses from congestion are wasted time, waste of fuel, stress, pollution, disruption of the smooth operation of emergency transportation such as ambulances and fire engines, and others [13-15]. The government of Bandung city, has performed various efforts to reduce traffic congestion, however congestions are still occur in many locations. This shows that the implementation of the prevention of traffic congestion in the city of Bandung has not been optimal enough [16, 17]. This, one of which is due to the inaccurate method and traffic engineering that is applied. Therefore, a system is needed that can predict traffic situations before and after the implementation of an engineering.

In this study, the authors propose a system that has capability to estimate traffic situations, called "LINTAS-BD 1.2" which is the development of the previous versions of the LINTAS application [18-21]. Furthermore, LINTAS-BD 1.2 in this article will be generally called as LINTAS. This system is in the form of application tools, which, in its operation is based on the field of Mathematics, in particular the queueing model and the theory of probabilities [22-26]. The LINTAS system is expected to be a support tool for road traffic’s manager to be more effective in implementing a method or a traffic engineering before it is actually implemented, so that the road congestion can be avoided or reduced.

LINTAS system is built with the latest technology based on models (a model-based application), not through some coding systems that are very vulnerable to errors. With model-based technology, LINTAS is made by combining several blocks in such a way as to form an integrated system unity. LINTAS was built as a puzzle, making it easier for researchers from various disciplines to participate in collaborating in developing systems. LINTAS is expected to be developed so that it can improve functions in accurately predicting traffic situations, simulating a method design and engineering before it is implemented, predicting the effect of the duration of traffic lights on the vehicle queue, calculating the effect of road parking on traffic jams, can evaluate contributing to the general irregularity of traffic congestion, predicting the causes of traffic congestion, finding solutions to the problem of congestion in various cities, especially in the city of Bandung in order to create a safe, orderly and smooth traffic atmosphere.

2. Theoretical Background

2.1. LINTAS: State of the art
Traffic congestion is a major problem in Indonesia, such as in Jakarta, Bandung, Surabaya, and other cities. Traffic congestion in the city of Bandung is commonly found on most of the road networks that exist during peak hours. To identify and learn about traffic jams, an understanding of Traffic Engineering is needed. The performance of roads and intersections is strongly influenced by the presence and arrangement of parking. Traffic is getting more complex every year, so it often creates new problems from various perspectives. In planning a traffic system, it is necessary to study the impacts that might occur later.
LINTAS is an application that designed to simulate traffic flows based on Mathematics’ model, specifically the queuing theory. LINTAS runs the simulations based on minimum three input parameters, including the average rate of vehicle arrivals per unit time, the average duration of time the vehicle is in a system (queues, traffic lights, train doors, etc.), and the capacity of the road. Based on the aforementioned parameters, LINTAS has capability to predict by simulation whether traffic congestion will occurs, the length of the queue of vehicles, the number of vehicles on a specific location, the length time of travel from one location to another, and another predictions that needed for traffic analysis.

Moreover, LINTAS has capability to predict traffic situations by simulation based on a certain traffic methods or traffic engineering. For example, changes from two lane direction into one lane direction, dynamic vehicle transfer, load balancing [27], traffic light engineering [21, 28, 29], and other traffic methods or traffic engineering can be implemented in the LINTAS. A simulation through the LINTAS will be able to ease the burden on traffic managers, so that the most appropriate engineering methods can be found to create a smooth and a non-congested traffic atmosphere.

LINTAS-BD 1.2 is an update system of the previous version that was developed in 2018 [18-21] with the following specifications:

1. Model-based design. LINTAS system is created using MATLAB-Simulink software, SimEvents Toolbox [27]. LINTAS is made by arranging several modules and connecting them through the connector. The model-based way is relatively simpler than coding, so researchers will focus more on application design, not preoccupied with errors due to coding errors.

2. Universal. Various input and output media can be connected to the LINTAS system. Input media include: online data, CCTV, and various types of input sensors. For media output, among others: monitors, websites, data that can be accessed by users through various tools.

3. Customize-able. The LINTAS system can be customized to implement a particular method or engineering. Furthermore, the method or engineering is simulated to predict the results of traffic conditions.

4. Accessible. The LINTAS system can be installed on cloud technology so that it is possible to be accessed by the public in need.

5. Friendliness Output. The output of the LINTAS system can be a graph or time series data that can be directly used for further observation or analysis.

In LINTAS-BD 1.2, there is a development of the system, including the more extended scope of the simulation.

2.2. Previous work

Simulation designs and modeling of traffic flow have been carried out by researchers. Among them is the modeling of traffic flows using Partial Differential Equations, and traffic flow modeling using Macroscopic and Microscopic Models in Ordinary Differential Equations. The disadvantages of modeling are only for traffic flows that contain four-wheeled vehicles.

There are many researchers who have made a simulation system for traffic, but in general, the simulations carried out are still partial or specific in certain cases. Among them are [28] and [26] which specifically simulate about intersection. There are also several other researchers who have partially examined traffic, only about the influence of pedestrians, market crowds or terminals on traffic congestion.

The LINTAS system was first introduced in March 2018 [19]. In this study, research was developed with simulation methods based on queuing theory. Simulation methods can provide a clear picture of the traffic situation before and has been applied to an engineering.

2.3 Queuing Theory

Queuing theory is frequently used in traffic analysis to understand and learn about the traffic congestion through several parameters: vehicle arrivals rate, queue length, queues waiting times, etc. Some basic
concepts of queuing model used in LINTAS are the arrival rate ($\lambda$), which is the average arrival of vehicles into the system per unit time. The rate of the process or service in the system ($\mu$) is that the average vehicle is processed and exits the queue system or traffic barriers per unit time. In this article it is assumed that the queue model used is M/M/c where $c$ is the number of servers indicated by real numbers. In the M/M/c model, the arrival process is Poisson with the arrival rate following an exponential distribution. Similarly, the rate of service follows an exponential distribution.

Based on the M/M/c queue model, the average queue length of the vehicle ($L$) in steady-state conditions is calculated based on the formula:

$$L = \frac{P_0(\lambda - \mu)^n \lambda/\eta\mu}{n! (1 - \lambda/\eta\mu)^2}$$

where

$$P_0 = \left[ \sum_{i=0}^{n-1} \left( \frac{\lambda/\mu}{i!} \left[ \frac{\lambda/\mu}{i! (1 - \lambda/\eta\mu)} \right]^i + \frac{\lambda/\mu}{i! (1 - \lambda/\eta\mu)} \right) \right]^{-1}$$

The queue length calculations are integrated in the Queue module in the LINTAS system. The results of the calculation of the queue length based on the Queue module for simulation time are infinite, giving convergent results with formula ($L$). Furthermore, the level of traffic density ($\rho$) is calculated based on the formula:

$$\rho = \frac{\lambda}{\mu}$$

where the average processing time is $1/\mu$. As with the queue length ($L$), the calculation of traffic density ($\rho$) has also been integrated in the Server module.

The queuing system can be described as the arrival of vehicles, and then they queues because of obstacles, and finally leaves the queue. The arrival model or pattern is one of the elements in the queue model. The pattern of arrival of vehicles defined by the interarrival time which can be stochastic or deterministic. The arrival pattern is deterministic if it remains or does not change, so that the arrival time between each vehicle can be determined. The arrival with deterministic pattern, results in a constant queue length. Another arrival pattern is a stochastic pattern, where the arrival time between vehicles is not fixed or uncertain and can be searched with a certain formula based on a distribution value. With a pattern of arrival that is not fixed to time, the queue length is also not fixed.

Services in the queue system for the number of services can be divided into two categories, namely single or plural services. The number of services depends on the number of vehicle arrivals. An authentic example is the queue of vehicles on the toll road door. If the number of arrivals is low, then one door service is sufficient. But if a high arrival occurs, so as not to cause a long queue, the service door must work faster. On the other hand, if the service speed has a certain average, then to avoid the queue of vehicles, another service door can be opened where the number of services is adjusted to the number of arrivals.

In this study, the M/M/c queue model was used, namely the Markov queue system where vehicle arrivals and services were said to be stable with a certain average. The arrival of vehicles is assumed to follow a Poisson process, service time is assumed to follow an exponential distribution, and is assumed to use a single service. The characteristics of the Markov queue system are ergodic, which will have the
same characteristics in a fairly long period of time, and the queue system is in a steady state condition. The arrival of the vehicle is represented by the variable $\lambda$, and the service is $\mu$.

3. Method

3.1. Data Collection
The data that will be used in this article is obtained through observations in the field, precisely in several locations of traffic lanes in Bandung city. The data is used for simulation consist as the data of arrival vehicle, duration time of traffic light, the number of vehicles that leaving the intersection with traffic light, queue-length, and waiting time in the queue and in the intersection. In the traffic light intersection, the duration of the red light and green light is obtained in units of seconds. We assume the yellow light is calculated as a green light because of its nature as a warning against color changes, and also because when the light is yellow, the vehicle keeps moving until it turns on the red light. Other variables collected were the arrival of vehicles, many vehicles in the queue, and the number of vehicles coming out of the four road segments.

3.2. Research Tools
In this article, we improve the simulation system of Bandung city that has been created [18-19]. The modelling is performed based on queuing theory with the M/M/c principle, while the simulation which consist the design of traffic simulator that arranged from block’s components, are created using the SimEvents MATLAB-Simulink software [30]. The SimEvents-MATLAB has been used as an application tool to simulate a proposed system in various fields, such as transportation [31, 32], Internet [33] specifically on Content Delivery Networks (CDN) systems and Service-oriented Routers [34-41]. Another methods are possible to be included in the simulation, such as load balancing, Bayesian networks [42-44], etc. The components of the simulator system using SimEvents are blocks or modules in the form of an entity generator block as a medium for generating entity (vehicles), server block as services, gate block as representations of traffic intersections, link block as representations of transportation routes, and sink block for entity eviction.

3.3. Design and Model of LINTAS
The implementation of the LINTAS simulator will be piloted at certain traffic locations in the city of Bandung. The LINTAS system that will be used is referring to the previous version of the system that has been implemented in one of the traffic locations, namely on Jalan Soekarno-Hatta Bandung [20]. Moreover, the LINTAS simulation system is prepared by using five main modules, namely the data generator package (entity generator) as the generator of number of vehicles, entity queue, module server (entity server) as a process / service module, terminator module to delete the data package used, as well as links as roads.

As stated in the second part that the queuing model in the LINTAS system is assumed to be M/M/c, the arrival rate is Poisson with the arrival pattern randomly following the exponential distribution. Likewise for the speed of the process or vehicle service. Thus, the generator block and server must be setup first as shown in Figure 1.
Figure 1. Parameter for the module of Entity Generator

The entity generator setting can also be set by using external modules as shown in Figure 2. The vehicle’s arrival rates data ($\lambda$) are entered manually by using constant block.

Figure 2. System model for Entity Generator

This $\lambda$ value is generated following an exponential distribution. This step is also applied to the average process input / vehicle service ($\mu$) following the exponential distribution on the server block. The value units of $\lambda$ and $\mu$ are vehicles per second, with values range $0 < (\lambda, \mu) < \infty$. 
4. Result and Discussion

4.1 Scope of Simulation Areas

The area coverage in LINTAS 1.1 is more extended compared to the previous version, with the central point of Bandung Islamic University, which covers a radius of up to 1.3 Km with 26 analysis focus points shown in Figure 3. At each point, an analysis of several traffic components is carried out. It is the arrival of vehicles, obstacles, duration of traffic lights, and others. Furthermore, the traffic components are used as input data to run the simulation.

![Figure 3. The simulation area of LINTAS-BD 1.2](image)

Furthermore, based on Figure 3, the LINTAS-BD 1.2 system was developed using the SimEvents MATLAB-Simulink application with reference to the previous version system. The appearance of the LINTAS 1.1 system is shown in Figure 4.

![Figure 4. The preview of LINTAS-BD 1.2 application](image)
Refer to Figure 3 and 4, all location have a basic model of simulator processing which consist of vehicle generator, queue area and delay/server, as depicted in Figure 5.

![Figure 5. The basic model of LINTAS’s Simulation Processing](image)

In Figure 5, vehicles coming into the system come from two sources. The first source is from another location, in this case comes from Ranggagading (Rg). The second source is from the entity generator, which is from the UNISBA subsystem. The vehicle generator model of the UNISBA subsystem as depicted in Figure 2. The arrival rate of vehicles is assumed to be following the Poisson process with the average vehicle speed exponentially distributed. Next, there are traffic intersections in several locations. For intersections with 4 directions and traffic lights, a model with the Entity Gate module is used as shown in Figure 6. In this module, the time duration of red and green light and can be set for each path.

![Figure 6. Simulator model for intersection road with entity gate module](image)

Setting the traffic light on the intersection module is processed in the Gate Control subsystem (Figure 6). The system design of the Gate Control subsystem are shown in Figure 7.
Traffic light setting is performed in the server block using a code of program. The red light and green light are determined by the duration of time each of which controls the Entity Gate module. During the duration of the red light, the program instructs the Entity Gate module to close the packet flow, while for the duration of the green light, the program instructs the Entity Gate module to open the packet flow. The command to open or close the data stream is done by using the GateCtrl(cmd) function.

5. Conclusion
In this paper a model and simulation of traffic at Bandung City is built and called as LINTAS-BD 1.2. The model is the development from the previous version, and works based on the queuing theory and the simulation is performed using SimEvents. Some of parameters can be included into the simulation for traffic engineering purposes. By using the simulation, hopefully it can support the government specifically the department of traffic to improve the traffic management. In the future work, the coverage area will be expanded, and some features will be added such as load balancing, changing number of lane, etc.

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7. References
[1] Manage 2019 Cibiru Bunderan Traffic congested, this is a tip to avoid traffic jams (Bunderan Cibiru Macet, ini tips supaya terhindar dari macet) [Online] http://www.suarapelita.com [accessed 12 June 2019].
[2] Halim H A 2017 Three proposals of Bogor regency government to reduce congestion at Puncak lane (Tiga Usulan Pemkab Bogor Kurangi Beban di Jalur Puncak) [Online] http://www.pikiran-rakyat.com [accessed June 2019].
[3] Jatinangorku 2014 Widening Efforts on Roads Constrained by Difficulties in Land Acquisition (Upaya Pelebaran Jalan Terkendala Sulitnya Pembebasan Lahan) [Online] https://www.jatinangorku.com [accessed June 2019].
[4] YLKI 2011 Vehicle restrictions, is it effective to solve congestion? (Pembatasan Kendaraan, Efektifkah atasi kemacetan?) [Online] http://ylki.or.id [accessed July 2019].
[5] Ravel S 2016 Congestion in holiday, traffic engineering is not effective (kemacetan liburan, rekayasa lalu lintas tak efektif) [Online] http://sains.kompas.com [accessed June 2019].
Suryowati E 2013Organda: Private vehicles the source of congestion (Organda: Kendaraan pribadi biang kemacetan) [online] https://money.kompas.com [accessed July 2019].

Retaduari E A 2017 These are various causes of severe loss in jakarta this monday morning (ini aneka penyebab macet parah di jakarta senin pagi ini) Detik News [Online] https://news.detik.com. [accessed June 2019].

Prakasa A 2017 Become the congestion source, the legendary terminal in Bandung will be demolished (Jadi biang macet, terminal legendaris di Bandung bakal dibongkar) Liputan 6 [Online] http://regional.liputan6.com [accessed April 2019].

Wahyunik S 2018 These are a number of causes of traffic congestion around the City of Malang’s Central Gadang Market (inilah sejumlah penyebab terjadinya keruwetan lalu lintas di sekitar pasar induk gadang kota malang) SuryaMalang.com [Online] http://suryamalang.tribunnews.com [accessed April 2019].

Cirebon R 2017 Disbanding School, congestion is getting worse (bubar sekolah, macet makin parah) RadarCirebon.com [Online] http://www.radarcrebon.com [accessed April 2019].

Rahayu C M 2017 The traffic light broken, light is only yellow, the intersection of Matraman is totally congested (lampu rusak hanya kuning, perempatan Matraman macet total) Detik News [Online] https://news.detik.com [accessed April 2019].

Rachman T 2015 losses due to traffic jams in Jakarta have reached Rp. 65 Trillion per year (kerugian akibat macet di Jakarta capai Rp 65 Triliun per tahun) REPUBLIKA [Online] http://nasional.republika.co.id [accessed April 2019].

Setiawan I 2016 Congestion at the railway crossing is critical (kemacetan di perlintasan KA kramat sentiong) Detik News [Online] https://news.detik.com [accessed June 2019].

Ramadhan A 2018 Congestion caused by flood (lalu lintas di jalan leten soeprazo macet akibat banjir,’ KOMPAS.com [Online] http://megapolitan.kompas.com [accessed June 2019].

Detik 2013 The difficulty of conquering fires in Jakarta: The action of fire extinguishers often hampered by congestion (sulitnya menaklukkan kebakaran di Jakarta: Aksi pemadam kebakaran sering terhambat kemacetan) Detik News [Online] https://news.detik.com [accessed July 2019].

Agustina A 2017 Overcome traffic jams, the Bandung city government will multiply buses (atasi macet, pemkot Bandung akan perbanyak bus) Merdeka.com [Online] https://bandung.merdeka.com [accessed June 2019].

Isprianto T 2017 Ridwan Kamil-Oded have not been optimal yet to solve traffic jams and floods (ridwan kamil-oded belum optimal selesaikan macet dan banjir) Detik News [Online] https://news.detik.com [accessed June 2019].

Harahap E 2018 LINTAS: Traffic Simulation System Using SimEvents MATLAB (LINTAS: Sistem Simulasi Lalu Lintas Menggunakan SimEvents MATLAB) [Online] https://erwin2h.wordpress.com [accessed July 2019].

Harahap E, et al 2018 LINTAS: Traffic Simulation System Using SimEvents MATLAB (LINTAS: Sistem Simulasi Lalu Lintas Menggunakan SimEvents MATLAB) Jurnal Ilmiah Informatika dan Komputer Politeknik Piikes Ganesha Bandung 10 1.

Harahap E, et al 2018 Improving Road Traffic Management by A Model-Based Simulation IEEE International Conference on Science and Technology (ICST 2018) Yogyakarta Indonesia.

Harahap E, et al 2019 LINTAS 1.1 Model and Simulation of Bandung City’s Traffic (LINTAS 1.1: Model dan Simulasi Lalu Lintas Kota Bandung) ETHOS: Jurnal Penelitian dan Pengabdian 7 2.

Harahap E, Badruzaman F H and Fajar M Y 2016 Model and simulation of transportation systems using queueing theory (model dan simulasi sistem transportasi dengan teori antrian) Matematika 15 1.

Harahap E, et al 2019 Modeling and simulation of queue waiting time at traffic light intersection J. Phys.: Conf. Ser. 1188 012001.

Harahap E, et al 2017 The effectiveness of Load balancing in reducing traffic congestion (Efektifitas load balancing dalam mengurangi kemacetan lalu lintas) Matematika 16 2.
[28] Harahap E, et al 2018 Queuing analysis of traffic at the intersection of buah batu – soekarno hatta Bandung (analisis antrian lalu lintas pada persimpangan buah batu - soekarno hatta bandung) Matematika 17 2 p79-85.

[29] Harahap E, et al 2019 A Design Simulation of Traffic Light Intersection using SimEvents MATLAB Sires Proceedings accepted.

[30] SimEvents Mathworks 2019 Model and simulate discrete-event systems running on MATLAB-Simulink [Online] https://www.mathworks.com/products/simevents.html [accessed July 2019].

[31] Harahap E, et al 2019 Traffic analysis at the lane of gatot subroto trans studio mall Bandung (Analisis lalu lintas jalan gatot subroto trans studio mall Bandung) Matematika 18 1.

[32] Harahap E, et al 2017 Queue Model with Dynamic Transfers to Reduce Highway Congestion (Model Antrian Dengan Pengalihan Dinamis untuk Mengurangi Kemacetan Jalan Raya) ETHOS Jurnal Penelitian dan Pengabdian 5 2.

[33] Harahap E, et al 2016 A Model-Based Simulator for Content Delivery Network using SimEvents MATLAB-Simulink International Series on Interdisciplinary Science and Technology (INSIST) 1 1.

[34] Harahap E, et al 2014 A router-based management system for prediction of network congestion IEEE 13th International Workshop on Advanced Motion Control (AMC) p398.

[35] Wijekoon J, et al 2017 Effectiveness of Service-oriented router for ISP-CDN collaboration Journal of Information Processing 25 45.

[36] Harahap E, et al 2013 Router-based Request Redirection Management for Next Generation Content Distribution Network GLOBECOM 2013 Workshop - GC13 WS - MENS 2013 Atlanta USA.

[37] Wijekoon J, Harahap E and Nishi H 2013 Service-oriented router simulation module implementation in ns2 simulator Procedia Computer Science 19 478.

[38] Wijekoon J, Harahap E and Nishi H 2012 SoR based request routing for future CDN 6th International Conference on Application of Information and Communication Technologies (AICT) Tbilisi Georgia

[39] Wijekoon J, et al 2016 How can a service-oriented router merge with a cdn? IEEJ Transactions on Electronics, Information and Systems 136 1172.

[40] Wijekoon J, et al 2013 Service-oriented router-based CDN system: An sor-based CDN infrastructure implementation on a real network environment COMPSACW ‘13 Proceedings IEEE 37th Annual Computer Software and Applications Conference Workshops.

[41] Wijekoon J, et al 2015 Effectiveness of a service-oriented router in future content delivery networks International Conference on Ubiquitous and Future Networks.

[42] Harahap E, Sakamoto W and Nishi H 2010 Failure prediction method for network management system by using Bayesian network and shared database in The 8th Asia-Pacific Symposium on Information and Telecommunication Technologies (APSITT) Kota Kinabalu Malaysia.

[43] Wijekoon J, et al 2015 Introducing a distance vector routing protocol for ns-3 simulator 8th EAI International Conference on Simulation Tools and Techniques Athens Greece p38.

[44] Harahap E, et al 2013 Distributed algorithm for router-based management of replica server in next-CDN infrastructure IEEE International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery Beijing China p266.