

## ORIGINAL

 OPEN ACCESS

Received: 09-04-2020

Accepted: 23-04-2020

Published: 14-06-2020

Editor: Dr. Natarajan Gajendran

**Citation:** Panhwar MA, Khuhro SA, Mazhar T, ZhongLiang D, Bilal MEA, Qadir N (2020) Li-Net: towards a smart Li-Fi vehicle network. Indian Journal of Science and Technology 13(18): 1821-1829. <https://doi.org/10.17485/IJST/v13i18.210>

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**Funding:** National High Technology  
863 programs of china  
(No.2015AA124103) and national  
key R&D program (No.  
2016YFB05502001)

**Competing Interests:** None

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## Li-Net: towards a smart Li-Fi vehicle network

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### Abstract

**Background/Objectives:** Light Fidelity is popularly known as Li-Fi. This is a most recent technology that was driven by German physicist Harald Haas<sup>(1)</sup> in 2011. The technology was proposed during a global talk on Technology Entertainment Design on VLC communications. Visible light communications are optical ways of communication that network the LED for data transmission. The term Li-Fi uses VLC communication for the high-end communication that can be an alternative to Wi-Fi. The proposal of Harald Haas is comparable with IEEE 802.15.7 that is the fully dual directional and networked standard built for 802.11. Li-Fi applications are featured for their comparison with other technologies like Wireless fidelity and their general use for LAN. **Materials and methods:** However, the optimality of the proposed Li-Fi is within highly dense areas where Wi-Fi faces interfaces and radio interferences are no good for complimentary performance goals of the communication standard. Li-Fi proves to be better in bandwidth, connectivity and secure when the higher speeds above 1Gbps are achieved. **Finding/novelty :** This study outlines the characteristics of Li-Fi and describes its potential use in a smart traffic net. The smart traffic net is the future of the transport system that is based on Li-Fi. Therefore, this is called Li-Net in this article. Li-Net is a modified VaNet that uses Li-Fi for V2V and V2I communication. The leveraging of Low cost LEDs and other lighting units have lots of opportunities that can help the Li-Fi to get over Wi-Fi.

**Keywords:** Li-Fi; Li-Net; VaNet; communication technology; network; smart network

### 1 Introduction

Nowadays, the world is overcrowded with wireless communications. This communication uses radio waves that transfer data from one place to another. These waves are very fast-growing network links that are very important for the day to day activities. The current wireless networks connect the whole world

with multiple device support and backward compatibility<sup>(2)</sup>. The availability of fixed bandwidth is, however, difficulty or the high-speed data transfers that also creates a vulnerability in the secure ways of data communication. The radio waves transmission is part of the EM spectrum that is used for the transmission of data. However, the new mechanism is broader in terms of data transmission technologies and provides more secure and faster communication using light waves, Li-Fi is also such a medium. The ideology of Li-Fi to transfer data using the quantization of LED lights<sup>(3)</sup>. The light is varied according to the speed of data transfer and hence human eyes cannot perceive the varying intensity<sup>(4)</sup>. Therefore, the data transfer can be accomplished. The visible spectrum of Gigahertz radio waves of data transfer is becoming the history in front of Li-Fi. LED bulb- A Primary component of Li-Fi Network is given in Figure 1.



Fig 1. LED bulb- A Primary component of Li-Fi Network<sup>(5)</sup>

The smart traffic net is the future of the transport system that is based on the Li-Fi net. Therefore this is called Li-net in this paper. This network is focused on allowing the stop signatories, signals, roadways that can direct the movement of automobiles and provide a fast and smooth ride for the safety of passengers. The autonomous cars can be operated by using radars and GPS with a vision of computers. The odometer of cars is also controlled by them that can also allow the V2V communication. Previous use of radio waves for this purpose is a very old technology that allows Vehicle-to-Vehicle and Vehicle-to-infrastructure communication. This technology is based on Li-Fi and is collectively known as V2X that allows both Vehicle-to-Vehicle and Vehicle-to-infrastructure communication. The smart traffic system allows and utilizes the Li-Fi network that avoids the radio airwaves and their potential fear of interference. For this reason TESLA autopilot system<sup>(6)</sup> can also be alternated. The system is currently being operated by TESLA and is no widely adopted and used for its potential benefits in public. The system is not in use for urban streets because it cannot improvise the rush and interferences in these areas. The system, on the other hand, uses wireless transmitters that are inefficient for their use in cars and communication with the infrastructure. Our proposed system uses light signals that did not require an additional transmitter and also can reprogram for the exchanging rate of flashlights. A transmitter bulb of Light fidelity consists of the following components. The Block diagram of Li-Fi Assembly is given Figure 2.

- Bulb
- PA circuit ( A RF power amplifier)
- PCB ( printed circuit board)
- Enclosure

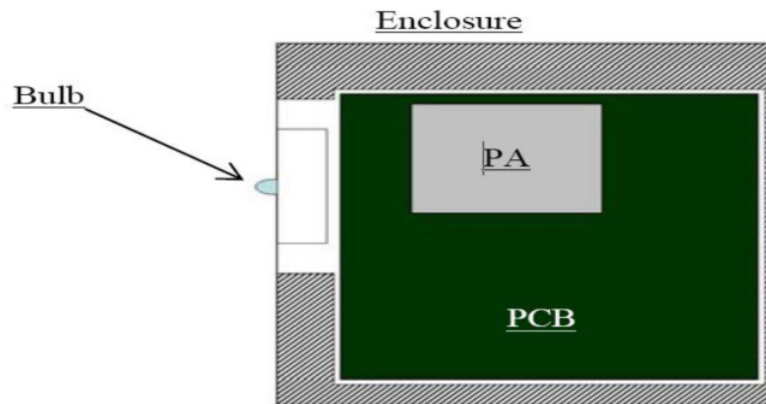


Fig 2. Block diagram of Li-Fi Assembly<sup>(7)</sup>

As the concept of LI-Net is described in this paper for the first time, there is no earlier literature to review on this topic. However, we review the concept of VANET and its relevant material for the Li-Net.<sup>(8)</sup> It states that in specific situations, a few RVs can communicate to a particular EV. Such an example can be in the case of parking. Where the vehicle doesn't know where to get an exit. Such a situation, movement on expressway movement & city activity can be coordinated, if a channel is shared between both of them.<sup>(9)</sup> described that Issues can arise if data goes undesired/pointless then these packets create issues. These issues can be either a collision on the roadway. This collision is due to contamination of the system by undesired immaterial data packets. The un-seen hub issue is a notable situation in remote correspondences which brings about a parcel smash. The situation includes two transmitters that are not in the gathering scope of each other and one recipient in the center.<sup>(10)</sup> Described that the collector is capable to listen to the two transmitters, however if one is sending data then the other will find the channel free and also sending data. This issue will cause a collision as VANet is not yet matured to use the ACK systems or synchronization mechanism. When the second transmitter starts sending packets, smash happens. The collector is getting vitality from the two transmitters at the same time making whatever is left of the parcel be gotten with mistakes. Given the idea of roadways being long lines, this circumstance happens frequently<sup>(11)</sup>.<sup>(12)</sup> stated that the equality of a DCC calculation is a critical factor that defines how all around appropriated an asset is. On account of V2V interchanges, reasonable utilization of the channel might be that everybody sends data at a similar speed, also the availability of medium may depend upon people's use of that medium in that area.<sup>(13)</sup> Also described the DDC algorithm that uses Beacon Error Rate. Error rate depends on the delay and loss of packets mostly due to congestion.<sup>(14)</sup> Beacon Reception Rate is dependent on sensitivity during the DCC analysis. It can be estimated as the quantity of data packets got from a particular vehicle in a characterized interim or the total of guides got from all vehicles per interim<sup>(15)</sup>. Inter-packets delay in transmission depends on the rate of getting packets by the reference point. Delay in channel access is the time that an EV faces before sending a data packet. A high value of access delay means that EV takes more time before transmitting packets.<sup>(16)</sup> described another measure known as the CBR ratio. This describes how much time a channel is kept busy. It depends on CCA (clear channel access). The CCA is a measure as how much a channel remained free for access.<sup>(17)</sup> research's main objective was to recognize crucial road portions and to protect the circulation block before it originally happens.<sup>(18)</sup>'s research emphasise on the features associated with circulation crescendos.<sup>(19)</sup> Presented 5 different interconnection patterns that form the foundation of nearly all applications of VANET. For future development, 5 different patterns may utilize its foundation. For secrecy and security analysis, patterns may form the foundation and permit the bottom-up conversation of security to obtain solutions for secrecy and security.<sup>(20)</sup> Shows extensive detail and matching of several obtainable VANET reproduction software and their modules. For detecting various layers of circulation blockage, the research emphasizes upon EDA which is an innovative technique to obtain a VANET message. Also, it focuses on atmospheric data

which comes from exterior data assets like weather situations.<sup>(21)</sup> Proposed a group of steering protocols known as road-oriented utilizing automobile circulation steering that works well with current steering protocols within city-oriented automobile ad-hoc systems. RBVT protocols' influence actual period automobile circulation data to make road-oriented ways comprising of progressions of street connection have a greater possibility, system connection between them<sup>(22)</sup>.

### **A. Primary attributes of Li-Fi Vehicle Network (Li-Net)**

Since Li-Fi Networks (Li-Net) acquire the vast majority of the qualities of magnets as their subset. Some exceptional qualities including high portability, density in-network, frequent topology change, communication patterns, power availability, no limitation on network size. As the batteries are rechargeable in vehicles so clients don't have a limitation on energy availability<sup>(23)</sup>. Moving hubs move with high speeds and are vehicles (above 100 Km). Therefore, a critical quality is a high portability. Additionally, topology regularly changes as vehicles move quickly or the drivers change their ways<sup>(24)</sup>. Due to movement in streets, the disengaged cluster is created as holes in the streets, additionally, topology change in Li-Fi Networks (Li-Net) shortens the length of the connection in length<sup>(25)</sup>. The vehicles will need much time to pick the new way to perform communication. As the density decreases, the isolated cluster increases. This will create connection disengagements. This will create issues that need to adopt roadside units and amplifying nodes. There is also a need for consistent availability and amplifying the messages in Li-Fi Networks (Li-Net)<sup>(26)</sup>. Portability is constrained to the arrangement of roadways, streets, and lanes. It is important to know the position of hubs to better anticipate the choice of the next receiver<sup>(27)</sup>. Also, as the portability model changes in parkways or urban conditions, it affects Li-Net control algorithms. The roadway model works better as one-dimensional movement is always shown over motorways. On the other hand, the urban model is affected by different patterns of the streets and multi-dimensional movements, density, plazas, and interferences by different trees & tall structures of buildings, etc. These highlights make the plan of Li-Fi Networks (Li-Net) in urban conditions unique and more difficult.

### **B. Communication Patterns in Li-Fi Vehicle Networks (Li-Net)**

In Li-Fi Networks (Li-Net) every vehicle may behave differently like a sender, recipient and switch to lead correspondences. Vehicle to Vehicle Communication (VC) can be stated as 1) "Inter-Vehicle Communication (IVC)", 2) "Roadside-Vehicle Communication (RVC)", and 3) "Hybrid Vehicle Communication (HVC)"<sup>(6)</sup>.

Inter-Vehicle Communication is the interchanges between different traveling vehicles that are free of frameworks. This correspondence is dependent on OBUs for completing the interchanges. Inter-Vehicle Communication is ordered into Single Hop Inter-Vehicle Communication and Multi-Jump Inter-Vehicle Communication interchanges. Single hop Inter-Vehicle Communication is mostly used in short-range correspondences like the applications who use path searching and other applications like that. Multi-hop Inter-Vehicle Communication is used for long-range correspondences like the movement observing applications. RVCs build up the correspondence amongst OBUs and RSUs. On the other hand, RVCs are further described in two categories. These are 1 sparse RVC (SRVC) and 2 Ubiquitous RVC (URVC).<sup>(26)</sup> The first category SRVCs give correspondence benefits as routing hotspots, while URVCs gives the fast interchanges to every one of the hubs. URVCs may require additional hardware. At long last, HVCs are utilized for correspondence purposes amongst running automobiles. Their other function is working as a base and supporting RVCs to broaden their scope territory. Likewise, if vehicles don't occur in the scope of the wayside framework, then other automobiles become a hotspot for HVCs. HVCs increment the transmission scope of RVCs. HVCs can't ensure the availability in low dense conditions. The [Figure 3](#) below exhibits the correspondence designs in Li-Fi Networks (Li-Net).

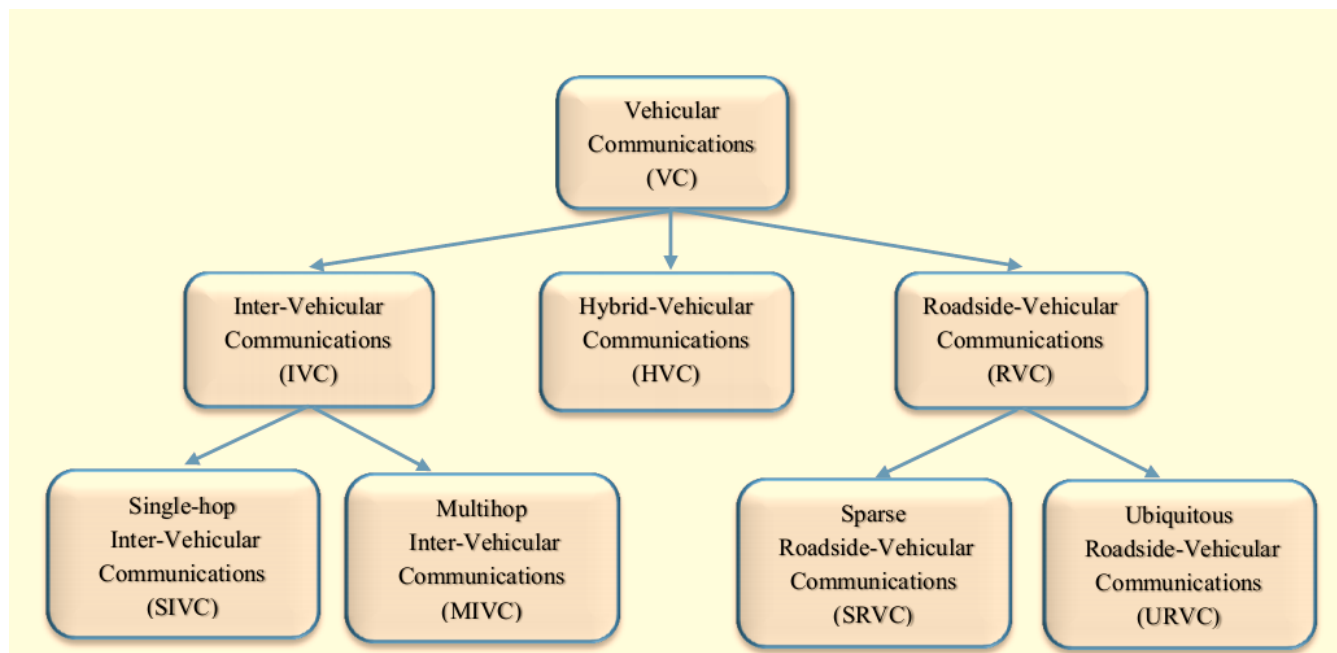


Fig 3. Communication Pattern in Li-Net

## 2 Problem Statement

Traffic congestions result from inefficiency issues of a network, and also issues like an adaptation of the technology. The same is the case with VANet. The VANet is considered as a new technology to overcome the traffic issues and correspondence between road traffic. As the quantity of vehicles develops quickly every year, more movement congestion happens on the roads, which is aimed to be solved by VANets, turning into a major issue for engineers in every metropolitan city.

During recent years, the work is done on congestion control activities. In earlier researches, congestion control is focused to packet loss amid the networked nodes. Now a days, the special characteristics of the VANets need to perform congestion control and to minimize delays and packet loss. This work focuses to develop a new strategy to control the congestion that will help to minimize the loss of packets and delay in transmission delay with the help of Li-Fi. Controlling congestion will help reduce the channel loads and efficiency of the network. This will also lead to the adaptation of the technology that is popularly known as Li-Net.

## 3 Li-Net Architecture

There are three domains of Li-Fi Network (Li-Net) incorporating into vehicle area, Ad hoc area, and the third one is infrastructure space. The in-vehicle area is framed of OBUs. Every vehicle is thought to be furnished with OBU. This is used during short-range remote correspondence that is produced by OBUs for security and non-critical safety transmissions. The ad hoc area is made out of combinations of OBUs and RSUs. There is a network between OBUs, this network is responsible for inter-vehicle correspondences. OBUs transmission is performed as one-hop correspondence or multi-hop transmission depending upon sender applications (shen et al, 2013). The infrastructure domain consists of RSUs and the second component is Hotspots (HS). This domain is utilized for safety-related and non-security applications. RSUs give web access, & Hot Spots are considered for low bandwidth conditions. For the situation that RSUs or HSs can't give web access, OBUs can utilize mobile systems architecture. These architectures include different networks like GPRS, GSM, UMTS, or any other for identification and Li-Fi for communication.

However, an efficient message of scheduling method for LI-NET is given in Figure 4.

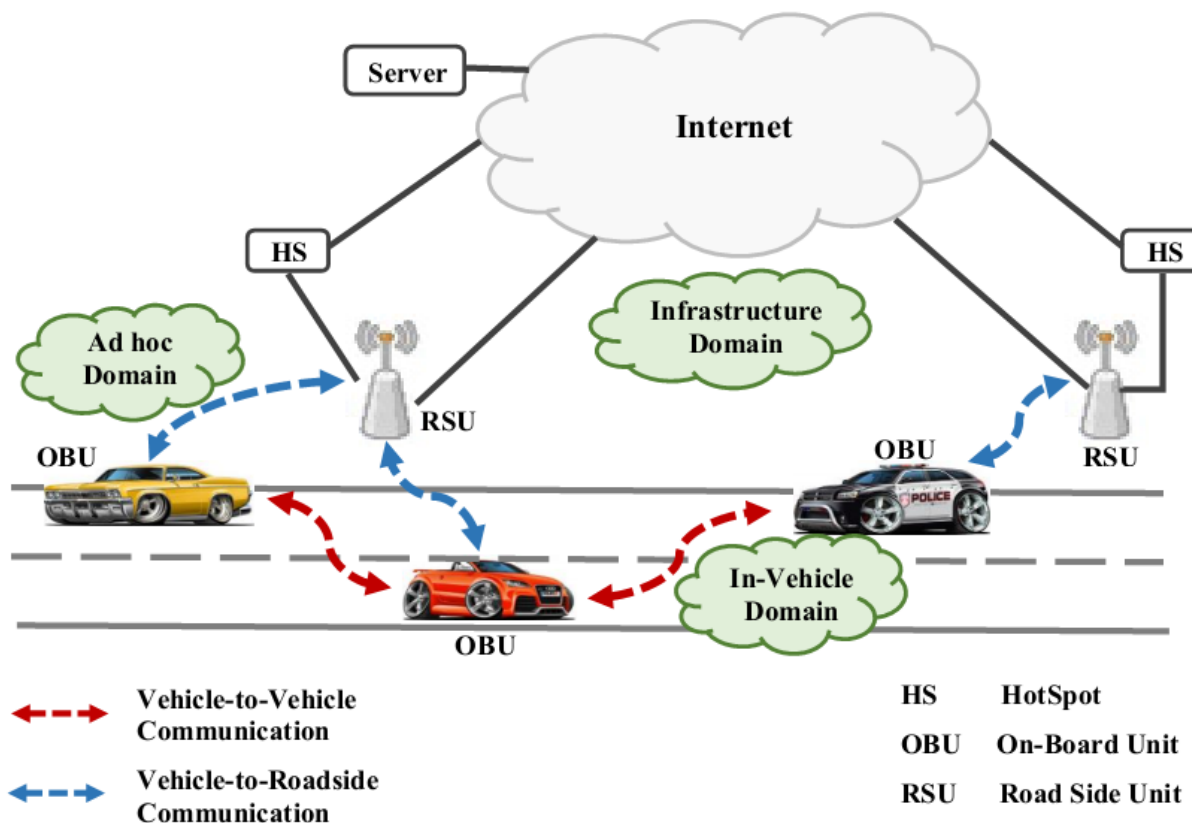


Fig 4. Li-Net Architecture

#### 4 An Efficient message scheduling method for Li-Net

The present paper proposes the use of meta-heuristic schemes that can be used for Li-Net scheduling. Due to the constraints of automobile atmospheres, simple arranging problems are said to be NP-hard, as described by<sup>(23)</sup>. Message arranging will also be an NP-hard problem. For such types of problems, meta-heuristic schemes result closer to find optimal solutions. Tabu algorithm as mentioned above is the best Meta scheme which are normally utilized for automobile routing and problems of graph theory etc. This algorithm is defined by<sup>(24)</sup>. For every medium, Tabu can be utilized for dynamic scheduling & re-arranging the procedure of messages. Dynamic scheduling approach can be based on Tabu, also mentioned as Tabu scheduling (St-Sch).

In LI-NETs, for giving reliable and secure atmosphere, message delay of transmission must be reduced. So, for minimizing delay, jitter remained the focus of this work through the use of Tabu as well. Memory schemes involve long, short and medium memories. A Tabu list is said to be a short memory that is used to store many solutions. When a new solution is picked for finding an appropriate solution then we put it into the Tabu list. After that new solutions contrasted with old solutions, to check if it is repeated or not. Size of the Tabu list should be 50 to put a threshold limit in this work. So, it can be assumed to be the limitation of the Tabu list. The old solution will be deleted from the list if a list has been filled and crosses over 50 solutions. For finding a better optimal solution, middle memory is utilized. Its size is 5 to put a check on maximum optimal solutions. Suggested Tabu also chooses an early solution between the lists of middle memory for creating new solutions. On the other side, a search is expanded using long

term memory to prevent set-up into local optimal solutions of short term and medium-term memory. So, presented algorithm, searches the best solutions from the Tabu list that contain many different solutions for message sending. In lines, neighborhood class described via altering the sequence of packets. The appropriate solution is picked between solutions within the neighborhood class and then kept into the applicant list. This way can provide solutions from the Tabu list. Within the proposed algorithm, the quantity of repetitions is supposed to be 25, as the size of queues is described as 50. Given below algorithm 1 present's pseudo-code of presented algorithm.

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Algorithm: Algorithm for Li-Net Scheduling

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```

Input size of Tabu list
input Iterations
Input counter Diversifications
Input current delay, jitter as So
Sout<-s0//initialize current solution as output solution
Divers Count<-0
Insert Tabu_list(S0ut)
i<-o// start iterations
intensifict_var<-0
intensifict_var_rand(1, iteration)
while(i<iterations)
N(s)<-find(neighbourhood set)// re-ordering packets as per mind-term-memory
T(s)<-find(TabuList)//re-ordering packets as per short-term-memory
CandidateList(s)<-N(s)+T(s)
Intensitic_Counter++++ If(Intensitic_Counter==intensifict_var)//randomly selecting solution from mid- memory
Sout<-select(midTermlist)
End if
If empty(candidate_list(s))long-term-memory
Divers_count+++
if Divers_count==diversification_counter//entrapping local minima
so<-genNewSoultion()
go to step 2//sout<-s0
End if
End if
End while
//update tabu_list step
If(length_tabuList<maxlistSize)
Add current Sout to Tabulist
Else Delete the o;dest solution in Tabulist
End if
End while
Return(Sout) //out_algo(Solution with Best Delay, Best Jitter, Ordered Queue

```

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## 5 Result comparison with trivial Vanet simulation

The proposed scheduling method for Li-Net message scheduling was tested using Intel Quartus Prime II. This software provides the simulation environment for the Li-Fi. The codes were separated for the sender and receiver node and then analyzed for their characteristics. It can be observed for different QoS characteristics for the potential outcomes of our proposal. The results are evaluated from the test bench code written in VHDL.

The proposed simulation was tested with the trivial VANET simulation as described by<sup>(6)</sup>. The scheduling in VAENT faces different issues like jitter, message delay, and message throughput issues. It is evaluated that in the case of Li-Fi, the vehicular network known as Li-Net worked smoothly in a congested urban environment with the proposed scheduling mechanism. Comparison results given in [Table 1](#).

**Table 1.** Comparison of result Characteristics (VaNet vs Li-Net)

Vehicle number	VANet			Li-Net		
	Lost Packets	Average Delay	Through Put Avg	Lost Packets	Average Delay	Through Put Avg
50	0	0	1	1	1	2
80	2	0	2	2	2	2.5
100	1.5	0.5	2	1.5	2	3
120	1.5	1.2	3	2	2	4
150	1.5	1.5	4	2	3	6
200	3	4	7	3	5	8

## 6 Conclusion

It illustrates the outcomes of highway situation, it is evident that the average delay of transmission grows with the growing count of automobiles for all blocking approaches. Also, it illustrates the average delay of transmission resultant from scheduling approaches are lower from VaNet. Li-Net based scheduling goes towards the smallest average delay of transmission. Tabu scheduling approach reduces the delay of transmission during transmitting a message for all sorts of messages. Li-Net scheduling approach also minimizes the average delay of transmission when compared to VaNet. There is an issue that FIFO is unable to manage congestion of transport when the quantity of transport goes high. Because in FIFO there is no priority and hence some packets are de-queued irregularly. The results table displays the packet loss for Va-Net and Li-Net scheduling. This is evidence that the loss of a packet is low in both scheduling when it comes to comparison. Congestion can be easily controlled when it comes to planning and prioritization. Priority can be assigned to safety and repair messages. This results in lowering down the measure of collisions and resultantly the loss of packets during transmission in Li-Net.

## Acknowledgment

The research work was financially supported by the National High Technology 863 programs of china (No.2015AA124103) and national key R&D program (No. 2016YFB05502001) and carried out in state key laboratory intelligent communication, Navigation, and micro-nano system, Beijing University of Posts and communications, Beijing.

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