An AI Fuzzy Clustering based Routing Protocol for Vehicular Image Recognition in Vehicular Adhoc IoT Networks

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Abstract

A vehicular ad-hoc IoT network (VA-IoT) plays a key role in exchanging the constrained networked vehicle information through IPv6 enabled sensor nodes. It is noteworthy to understand that vehicular IoT is interconnection of vehicular ad-hoc networks with the support of constrained IoT devices. Routing protocols in VAN-IoT is designed to route the vehicular traffic in the distributed environments. In addition, VAN-IoT is designed to enhance the road safety by reducing the number of road accidents through reliable data transmission. Routing in VAN-IoT has a unique dynamic topology, frequent spectrum, and node handover with restricted versatility. Hence, it is very crucial to design the hybrid reactive routing protocols to ensure the network throughput and data reliability of the VAN-IoT networks. This paper aims to propose an AI based Reactive Routing protocol to enhance the performance of the network throughput, minimize the end-to-end delay with respect to node mobility, spectrum mobility, link traffic load and end-to-end network traffic load while transmitting the vehicular images. In addition, the performance of the proposed routing protocol in terms of image transmission time is being compared with the existing initiative-taking and reactive based routing protocols in Vehicular Adhoc IoT (VA-IoT) Networks.

1. Introduction

Internet of Things (IoT) can be defined as the- Network of physical objects (Things) which can be embedded with IPv6 enabled sensor nodes [1,2]. In addition, these IPv6 enabled sensor nodes can be interconnected with other technologies like VANET, MANET, wired networks, Bluetooth etc. to exchange the data with other networked devices and systems over the internet. In IoT networks, each IPv6 enabled sensor detects its neighbor node and transmits the constrained information to the gateway through its neighboring nodes using multi-hop communication. Some of the real-time applications of IoT networks include industrial automation, disaster management, smart cities, smart grid, and automated healthcare Systems [3]. For such applications, a sensor node discovers the path to the neighbor nodes, builds the network topology and forwards the sensed data to the gateway. The operation of IoT system is mainly based on efficient networking mechanisms to facilitate interconnected heterogeneous traffic across different networks. VA-IoT (Vehicular IoT) network is specifically proposed to transmit the constrained vehicular information through the wireless networks that is shown in Figure.1. It is incredibly significant to design a routing protocol that must consider the device characteristics and constrained network and node resources to reliably transmit the application data. In addition, the IPv6 enabled sensors can have an unfavorable environmental factor that can drain the node energy, limited memory, and limited processing capabilities. Routing in VAN-IoT is a challenging task due to the node mobility, channel mobility and dynamic changes in the network topology. Due to this, the structure of the VAN-IoT network changes very quickly and the packet needs to be transmitted with more reliable routes to the destination. The state-of-the-art routing protocols proposed for VAN-IoT is specifically designed to address the route discovery in between source to destination [4-6]. But it is important to understand and analyze the performance of existing routing protocols to ensure the performance of VAN-IoT networks. In addition, the signal transmission range depends upon the coverage area which shows that nodes can only communicate with other neighbors that are within the range of node signal transmissions. In other words, a multi-hop communication is needed when the source and destination is being connected to different networks. Due to this, the vehicular nodes(routers) within the VA-IoT network must cooperate with each other to forward the application data from the source to the destination [7]. To transmit the information from the source to the destination, the network must be connected. In other words, nodes within the network must be capable of finding other nodes within the communication range to forward the application data from source to destination that in different geographical locations. The physical communication through radio signals is transmitted through Dedicated Short-Range Communication (DSRC) operating at 5.9GHz through IEEE 802.15.4 standard. The Wireless Access in Vehicular Environments (WAVE) is built with the specifications based on American DSRC that divides the spectrum into seven 10 MHz channels. Since the pattern is being proposed for vehicular adhoc communication, the node velocity, signal transmission radius and data transmission rate is being predetermined within the communication medium for application data transmission [8-11].

Based on the WAVE characteristics, the maximum node velocity will be up to 190 Km/hr., transmission radius is up to 1 km in noise free environment and transmission speed could be up to 27 Mbps in VANETs. The network layer in the TCP/IP protocol stack is responsible for defining the rules of packet routing in the public switched networks. The packet routing process is defined as the service responsible for discovering and keeping the end-to-end routes in between the source and the destination. The routing protocols are classified in terms of following parameters, Type of architecture and operation mode [12]. The operation mode is implemented based on the routing type, which can be further divided into topology, geographic, opportunistic, and data dissemination. This paper aims to compare and classify the existing routing protocols for VA-IoT networks to emphasize the significance of end-to-end throughput and delay while transmitting the constrained IoT data through the vehicular nodes. Later, this paper proposes a hybrid reactive routing protocol that supports both static and dynamic network topologies of the VA-IoT networks. In this paper, Artificial Intelligence The rest of the paper is organized as follows. Section-II briefly explains about the existing routing protocols that are being proposed to use in the VAN-IoT networks. Section-III briefly explains about the operation of existing routing protocols in VAN-IoT networks, Section-IV compares the existing routing protocols in terms of network throughput, channel mobility, node mobility and link quality. Section-V ends up with the conclusion and future work.

2. Related Works

IETF (Internet Engineering Task Force) propose RPL (Ripple for Low Power and Lossy Networks) as a standard routing protocol for low power radio devices.

ROLL-RPL supports the routing in traditional sensor networks by enabling the routing in public switched distributed networks through 128-bit IPv6 address [18].

The proposed RPL protocol can be used to connect IoT-to-IoT networks, IoT-to-other gateway networks and other gateway networks-to-IoT networks. In this sense, the constrained application traffic can be routed within the IoT networks i.e., both source and destination are in the same network (shown in Figure.2). It can be routed from IoT network to different gateway (shown in Figure.3) or it can be even routed from different gateway to IoT networks (Shown in Figure.4). But, with a few modifications in IP protocol stack, it is difficult to enable routing in sensor networks to be operated in the heterogeneous networks[13-16]. This is because traditional IP protocol stack is mainly designed with the assumption of operating with high data supportable rates whereas in IoT networks it is completely constrained in terms of radio and network resources. One approach to integrate the traditional wireless networks with the IPv6 enabled sensor network is with the support of tunnelling. But the implementation of tunneling on IPv6 transition is difficult to interoperate the heterogeneous networks because IPv6 is mainly used for 6LoWPAN protocol which runs over IPv6 network [17]. This will not provide a way to utilize an existing IPv4 routing infrastructure to carry IPv6 traffic that was generated through IoT networks. 6LoWPAN adaptation layer is mainly proposed to compress and fragment the IPv6 packets in order to support the packet length in IEEE 802.15.4 networks. RPL protocol also known as RIPPLE protocol is being proposed as a standard routing protocol for the IoT data transmission. State-of-the art routing protocols mainly focus on finding the shortest path in between source and destination through proactive static routing protocols. But, in the reality, the end-to-end routes in the vehicular IoT networks can’t be directly discovered through the static routing protocol due to node mobility, channel mobility and the constrained network resources. In traditional RPL routing protocol, route discovery can be done for three diverse types of scenarios [19-21]. The first scenario is used to discover the path when source and destination is in the same network. Figure.2 briefly explains the flow of operation when both the source and destination are in the same network. The second scenario explains about when both source and destination is completely in the different network. In this case, data will go through RPL routing protocol until it reaches to the gateway (see Figure.3), from gateway it uses a traditional wired routing protocol to reach to the destination node. The third scenario explains about the source and destination in the same type of network but connects in different geographical locations. In this case, traditional RPL is used from source to gateway, existing wired or wireless routing protocols will be used from the source gateway to the destination gateway and again RPL will be used from destination gateway to the destination node (see Figure.4). When it comes to the vehicle IoT nodes, data transmission can be possible within the same network or different network or same networks but in different geographical locations [22]. Since traditional RPL is initiative-taking and mainly designed for the static IoT network, it can’t be directly implemented in the vehicular IoT networks. In addition, it is significant to consider the different routing scenarios at the time of discovering the route in between source and destination. For example, sometimes the nodes might be moving and sometimes the nodes might be in the static mode. In this case, it is important to not use the same routing protocol for the node mobility scenario and static node scenario. All the vehicular nodes may not be continuously moving for the entire day. At the time of route discovery, based on statistical information through Artificial Intelligence (AI) algorithms, it is relatively easy to know how long the node can be static for data communication. Based on the statistical information from the AI algorithm, the scenario-I will have all static nodes within the network which can be used for data forwarding in between the source and the destination. In scenario-II, a different variant of the routing protocol will be triggered when only the subset of the vehicular nodes within the network are static. In scenario-III, a different variant of the routing protocol will be triggered when the entire nodes in the network are completely dynamic. Hence, in this paper, a hybrid routing protocol is being proposed to enhance the performance of the vehicular network by considering three different scenarios based on the statistical information from the AI algorithm [23]. Moreover, in the existing approaches, there is no single routing protocol that is being proposed to enhance the performance of the vehicular IoT network in terms of node mobility, channel/spectrum mobility and the channel-route maintenance [24]. In this paper, a hybrid reactive routing protocol is being proposed by considering three scenarios namely:

1. when the nodes are completely static (no node mobility).

2. when part of the nodes in the network are static and part of the nodes in the network is dynamic and

3. all the nodes within the network are completely dynamic.

The performance of the proposed reactive routing protocol is compared in three different scenarios with existing solutions through analytical analysis and the experimental results.

3. Proposed Work

In the first scenario, it is assumed that both the source and destination is in the same network (see Figure.2) and nodes within the vehicular IoT is completely static. This case is true when public transportation is in communication during parked mode. In this case, a reactive point-to-point routing protocol is being proposed in this paper to discover the routes from Source to Destination to transmit the constrained node application data. In the second scenario, it is assumed that some of the nodes in the network are static and some other nodes within the network are completely dynamic. This case is valid when the parked vehicles are allowed as a forwarding agent within the IoT vehicular networks. In the third scenario, all the nodes are assumed to be completely dynamic, stating that are the nodes are continuously moving to various locations. In this paper, a statistical data set with the Artificial Intelligence Algorithm is being used to select the whether the Vehicular network is in static mode or semi-static mode and completely dynamic mode. Based on the output of the AI algorithm, the routing protocol is being selected to discover the route in between Source and the destination. To attain this, statistical information is being collected to predict the node mobility scenario of the vehicles in a particular location. Due to recent developments in automation, Artificial Intelligence and machine learning techniques play a key role in determining the perfect decisions in various vehicular IoT applications. Artificial Intelligent technology is more related to the layer responsible for presentation and different functionalities in the vehicular IoT systems. In vehicular IoT systems, efficient computation of the shortest routing from source to sink, by intelligently choosing which routing protocol to be used when it is needed, and caching problems are most challenging problems. AI in vehicular IoT systems address most of these challenges. Interaction with AI in vehicular IoT provides optimizing the overall vehicular IoT network utilization. The AI layer in vehicular IoT systems consists of expert systems and big data management. It plays a key role in essential tasks such as storing, processing, selecting based on previous data and analyzing the data received from different layer and takes decisions based on the network structure and status. In this paper, three different routing protocols are being proposed to use based on the output of the supervised learning. When supervised learning predicts that the vehicles in the IoT networks are completely static then initiative taking based RPL routing protocol is being used to discover the routes from the source to the destination. When the supervised learning predicts that only the subset of the vehicles within the IoT network is static then the AODV-RPL with is being proposed to discover the routes from the source to the destination. When the supervised learning predicts that vehicles in the IoT network are completely dynamic then the opportunistic routing protocol like MaxProb, Vehicle Assisted Data Delivery (VADD) is being proposed to discover the routes in between Source and the Destination. In all the three different scenarios, there will be a route discovery phase followed by the data transmission phase. In case-1, route discovery is completely initiative-taking, in the sense, route is assumed to be available when the data reaches to the network layer of the IoT gateway. In case-II, routes will be discovered through route request and route reply to messages when the data reaches the network layer. In case-III, opportunistic routing is used to discover the routes when the data reaches the network layer of the IoT vehicular gateway. The analytical analysis for the three different routing protocols is briefly explained below.

$$Throughput_{max} = \left(\frac{Total_{Databits}}{Delay}\right) = \left(\frac{Total_{Databits}}{T_{Prop} + T_{PUfreeChannelTable} + T_{DCF}}\right)$$

$$Throughput\left(\frac{Total_{Databits}}{T_{DCF} + T_{PUfreeChannelTable}}\right)_{max}$$

$$T_{DCF} = \begin{Bmatrix} N * T_{RTS} + N * T_{SIFS} + N * T_{CTS} + N * T_{SIFS} + T_{DATA} + N * T_{SIFS} + \\ N * T_{ACK} + N * T_{DIFS} + N * T_{Backoff} \end{Bmatrix}$$

$$T_{DCF} = \begin{Bmatrix} N * T_{RTS} + N * T_{SIFS} + N * T_{CTS} + N * T_{SIFS} + \left(N * T_{PR} + N * T_{PHY} + \frac{8(L_{MAC} + MSDU)}{Datarate}\right) + N * T_{SIFS} \\ + \left(N * T_{PR} + N * T_{PHY} + \frac{8 * L_{ACK}}{Datarate}\right) + 2*N*T_{slotTime} + N * T_{SIFS} + \left[\frac{(CW_{min} * T_{slotTime})}{2}\right] \end{Bmatrix}$$

$$T_{PUfreeChannelTable} = \left\{N * T_{PR} + N * T_{PHY} + \frac{8(n * L_{PUfreeChannelTable} + L_{senderIP} + L_{senderMAC})}{Datarate}\right\}$$

$$Throughput\left\{\frac{Total_{Databits}}{\begin{pmatrix} N * T_{PR} + N * T_{PHY} + \frac{8(n * L_{PUfreeChannelTable} + L_{senderIP} + L_{senderMAC})}{Datarate} + N * T_{RTS} \\ + 4*N*T_{SIFS} + N * T_{CTS} + 2 * N * (T_{PR} + T_{PHY} + T_{slotTime}) + \frac{8(L_{MAC} + MSDU + L_{ACK})}{Datarate} \end{pmatrix}}\right\}_{max}$$

$$CW_{min} = 31, T_{slot_{Time}} = 20\mu s, T_{DIFS} = 50\mu s, T_{SIFS} = 10\mu s$$

$$T_{SIFS} = 10\mu s, T_{PR} = 144\mu s, T_{PHY} = 48\mu ns$$
$$L_{MAC} = 34bytes, L_{DATA\_payload} = 0 - 2312bytes.$$

$$L_{ACK} = L_{CTS} = 14bytes, T_{CTS} = N * T_{PR} + N * T_{PHY} + \frac{8 * L_{CTS}}{ACKrate}$$
$$T_{Backoff} = 310\mu s$$
$$L_{RTS} = 20bytes, T_{RTS} = N * T_{PR} + N * T_{PH} + \frac{8L_{RTS}}{RTSrate}$$
$$L_{PUfreeChannelTable} = 12bytes$$
$$Throughput\left\{\frac{Total_{Databits}}{N*\left(1872 + \frac{8(L_{MAC} + MSDU + L_{ACK})}{Datarate}\right)}\right\}_{max} \qquad (1)$$

The end-to-end network throughput in (1) is calculated for three different scenarios. When the node in the network is completely static then it is assumed that there are no frequent link failures due to node mobility and node inflight packet drops. In this case, the achievable node throughput is close to the channel saturation level. When the node in the network is semi-static in case-1, route discovery is completely initiative-taking, in the sense, route is assumed to be available when the data reaches to the network layer of the IoT gateway. In case-II, routes will be discovered through route request and route reply to messages when the data reaches the network layer. In case-III, opportunistic routing is used to discover the routes when the data reaches the network layer of the IoT vehicular gateway. The analytical analysis for the three different routing protocols is briefly explained below. In the network throughput calculation (see equation.1), ‘N’ stands for number of times the communication channel gets re-constructed due to packet drops in between sender and receiver. The packet drops are mainly due to node mobility, channel quality deterioration due to heterogeneous traffic flow and the congestion at the routers.

Table 1: Simulation Parameters

Name of the Parameter	Description
Topology	1000 *1000 Flat grid
No. of IoT nodes	100
No. of non-overlapping channels	3 channels
Spectrum band	2.4 GHz ISM bands
Input transmit power	20dBm
Node coverage area	50 meters
Interface Queue length	20
Data rate	250 kbps
Antenna Type	Omni-directional
Beamwidth	360 degrees
Simulation time	100 Sec
Traffic type	CBR/UDP

In scenario 1, the channel reconstruction is close to 1 i.e., N=1. This is because the nodes in the vehicular adhoc IoT network are completely static. Whenever the nodes in the network are static then there is no link failure due to node mobility and the spectrum mobility. But there could be a packet drops due to congestion at the routers which will not lead to channel link reconstruction at the link level of the vehicular IoT networks. In scenario 2, the subset of the nodes is static, and subset of the nodes are dynamic. In this case, the N value increases due to node mobility and channel mobility while transmitting the data in between sender and the receiver. Whenever ‘N’ value increases then the achievable network throughput decreases due to increased control message overhead within the network. Hence, theoretically achievable network throughput in scenario-2 is less than secenario-1. In scenario 3, it is assumed that the nodes within the vehicular IoT network is completely dynamic and there is very frequent spectrum mobility. In this scenario, the ‘N’ value is extremely high due to increased network and channel instability due to node and spectrum mobility. In this scenario, theoretically the achievable throughput is much lesser than achievable throughput in scenario-1 and scenario-2. Hence, it is not suggestable to use the conventional reactive on-demand based routing protocols when there are extremely high dynamics in the topology of the vehicular IoT networks for image transmission. In real-time scenario, when images are being transmitted from sender to receiver, then UDP is used as a transport layer protocol to reduce the control overhead in terms of the Acknowledgments. In other words, unreliable UDP transport layer protocol is being used to provide the end-to-end connectivity for the image transmissions whereas routing protocol changes from scenario-1 to scenario-3 based on the recommendation of the supervised machine learning algorithms. The experimental analysis further explains how the routing protocol will be dynamically changed to enhance the performance of the network in terms of end-to-end throughput and network delays through supervised learning approaches.

4. EXPERIMENTAL WORK

Network Simulator with the support of vehicular IoT devices is implemented and evaluated to analyze the performance of the vehicular adhoc IoT network. Three different scenarios were used to check the performance of the vehicular IoT networks in terms of the aggregate network throughput and the average end-to-end delay. In addition, the performance is compared with RPL which is an initiative-taking constrained routing protocol. The parameters used in this simulation is represented in the table. 1. Initially, the network topology of 100 IoT nodes are created in a 1000*1000 flat grid area. RPL, a traditional initiative-taking routing protocol is simulated to transmit the point-to-point(P2P) traffic flows in between the sender and receiver. Aggregate network throughput and end-to-end delay is calculated for the point-to-point traffic flows through RPL routing protocol. Aggregate throughput and end-to-end delay are calculated with three scenarios (static network topology, semi-static network topology and dynamic network topology). Aggregate network throughput and the end-to-end delay is evaluated for all the three scenarios using RPL routing protocol. Subsequently, the network metrics are simulated with the P2P-RPL and AODV-RPL routing protocols. Initially, the performance metrics was evaluated with RPL, P2P-RPL and AODV-RPL is evaluated for the static vehicular IoT network. Figure.5 explains about the aggregate network throughput with respect to the data rate in between source and destination. As shown in Figure.5, aggregate throughput is compared with three different scenario’s namely static networks, semi-static network (subset of the nodes are in mobility) and dynamic network. Aggregate throughput is evaluated initially with 100 nodes then it gets increased to 1000 nodes. As the number of nodes within the network increases then the achievable throughput gets decreased due to increased control overhead. RPL and P2P-RPL are evaluated for the static scenario. Since network is completely static, there is no packet drops due to node mobility and channel mobility in the static scenario. But the achievable throughput in RPL routing is less in comparison with P2P-RPL and AODV-RPL. This could be mainly due to the increased delay in transmitting the application data. In RPL, increased delay is due to forwarding the data to the IoT-gateway even though the destination is in the same network. In point-point to networks, AODV-RPL and point-to-point RPL discover the routes through Route Discovery and Route Reply messages. Hence, there is no need to transmit the application data to the IoT gateway. But, in initiative taking based RPL routing protocol, data always needs to be forwarded to the IT gateway even though the destination is next hop towards the source node. This increases the delay in transmitting the application data to the destination IoT node. Since vehicle images are being transmitted from source to destination, unreliable UDP protocol with Constant Bit Rate (CBR) is being used in between the source and destination. Hence, there is no guarantee that each data packet of the image is successfully reach to the destination. Furthermore, the route towards the IoT gateway in the RPL is periodically updating which could result in change in the path towards the destination from the source vehicular IoT node. Due to this, the achievable throughput for the RPL networks is relatively low when compared with AODV-RPL and P2P-RPL with static, semi-static and dynamic network topology scenarios. AODV-RPL Scenario-1 (Static vehicular IoT Network): In this scenario, nodes in the network are assumed to be completely static. In the experimental analysis, traditional RPL and point-to-point RPL are evaluated with only Scenario-1. Since data is hop-by-hop forwarding in AODV-RPL, whenever the destination is close to the source then the end-to-end transmission delay through AODV-RPL is very less.

This in turn results in increased aggregate network throughput in between the source and destination. Hence, aggregate network throughput for AODV-RPL scenario-1 is relatively high in comparison with RPL, P2P-RPL and AODV-RPL with scenario-2 and scenario-3. In addition, the packet drops due to node mobility are almost negligible and the packet drops due to the buffer overflow at the intermediate node is reduced with a greater extent in comparison with the other existing initiative-taking and reactive based routing protocols. This clearly shows that aggregate network throughput and the average end-to-end delay for AODV-RPL in scenario-1 is better compared to other scenarios of AODV-RPL, P2P-RPL and RPL routing protocol. AODV-RPL Scenario-2 (subset of the nodes in the vehicular IoT network are dynamic): In AODV-RPL scenario-2, it is assumed that only few nodes within the 1000*1000 flat grid are in mobile and rest of the nodes in the network are static.

In this scenario, there is a possibility of the frequent channel re-construction due to spectrum and node mobility in between the sender and the receiver. This in turn results in increased application packet drops in between the sender and receiver. Whenever there is node and spectrum mobility in vehicle IoT networks, then there is an increased route control overhead that results in decreased application data transmission. This directly affects the achievable aggregate network throughput and increases the data transmission delay between sender and the receiver. Due to this, there is decreased aggregate throughput with AODV-RPL scenario-2 in figure.5 when compared with P2P-RPL and the AODV-RPL with scenario-1.

AODV-RPL Scenario-3 (Nodes in the vehicular IoT network is completely dynamic): In this scenario, nodes in the vehicular IoT network are assumed to be highly dynamic. In other words, the vehicle IoT networks is going to have a very frequent channel and node mobility. When there is high channel and node mobility, communication links are highly unreliable which results in increased application packet drops. That’s why, the achievable aggregate throughput in the Figure.5 is much lesser for AODV-RPL scenario-3 in comparison with the RPL, P2P-RPL and AODV-RPL with scenario-1 and scenario-2. Whenever the channel reconstruction time increases then the network will be engaged with control message transmissions instead of original application data. It is noteworthy that when the RPL and P2P-RPL is implemented onto the dynamic network scenario then the performance of the RPL and P2P-RPL routing protocol is much lesser than the throughput achieved in the AODV-RPL with scenario-3. Figure.6 briefly explains the end-to-end delay with respect to the number of data packets that is being sent in between source and the destination. From Figure.6, there is higher delay when the number of nodes within the vehicular IoT network gets increased. This is due to increased collision rate during channel access and increased congestion at the intermediate IoT devices. In addition, the average end-to-end delay for the AODV-RPL with scenario-3 is extremely high in comparison with the other initiative-taking and reactive routing protocols. This is due to the increased node mobility and frequent topology changes within the network. Figure.7 explains about the aggregate network throughput with respect to number of data packets with application packet size as 127 bytes. When the size of the data packet increases then the achievable throughput increases due to reduced control overhead. In other words, the header overhead reduces with the increased application packet size. Figure.8 explains about the average end-to-end delay with respect to the number of data packets for packet size as 127 bytes. It is obvious that the average end-to-end delay for increased packet size is lower than the average end-to-end delay with smaller size packets. Figure.9 explains about the aggregate network throughput with respect to number of IoT nodes whereas Figure.10 explains about the end-to-end delay with respect to number of IoT nodes in vehicle IoT networks.

5. CONCLUSION AND FUTURE WORK

End-to-end network throughput and the average network delay plays a crucial role in enhancing the performance of the vehicular IoT networks. To attain this, selecting an efficient routing protocol is important in different network scenarios. This paper proposed an AI based Routing protocol selection based on the different network scenarios. Based on statistical information of network topology, initiative-taking (RPL) or reactive routing protocol (P2P-RPL, AODV-RPL) is being selected to transmit the application data from the source to destination in the vehicular IoT network. Based on the simulation results, AODV-RPL enhances the network throughput with minimized average end-to-end delays for point-to-point traffic flows. When the network topology is highly dynamic then the achievable throughput through AODV-RPL is also minimal. To improve, opportunistic routing protocol is planned to be proposed as a future work for highly dynamic network topologies.

Declarations

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Figures

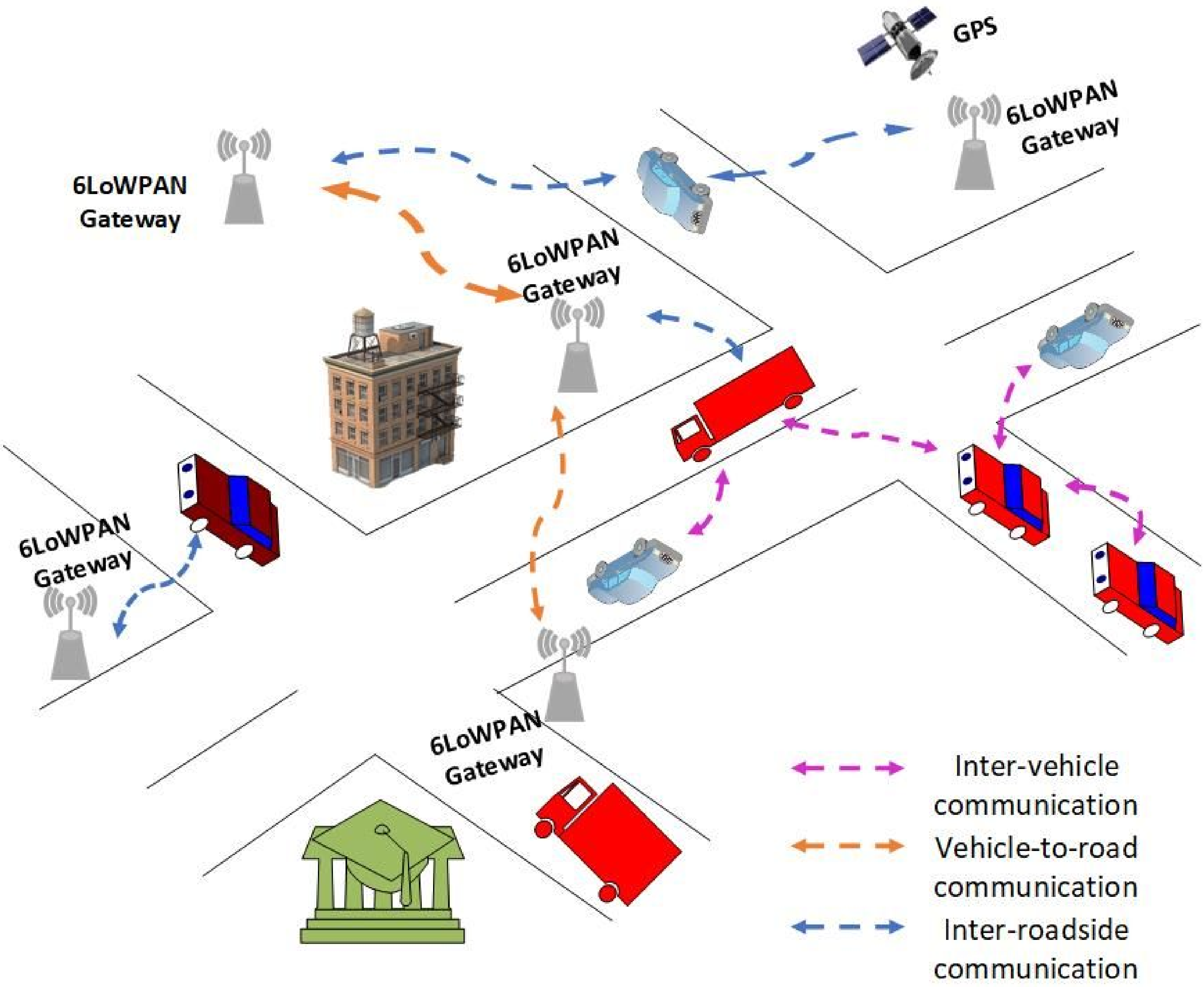

Figure 1

Overview of IoT in vehicular Adhoc Networks.

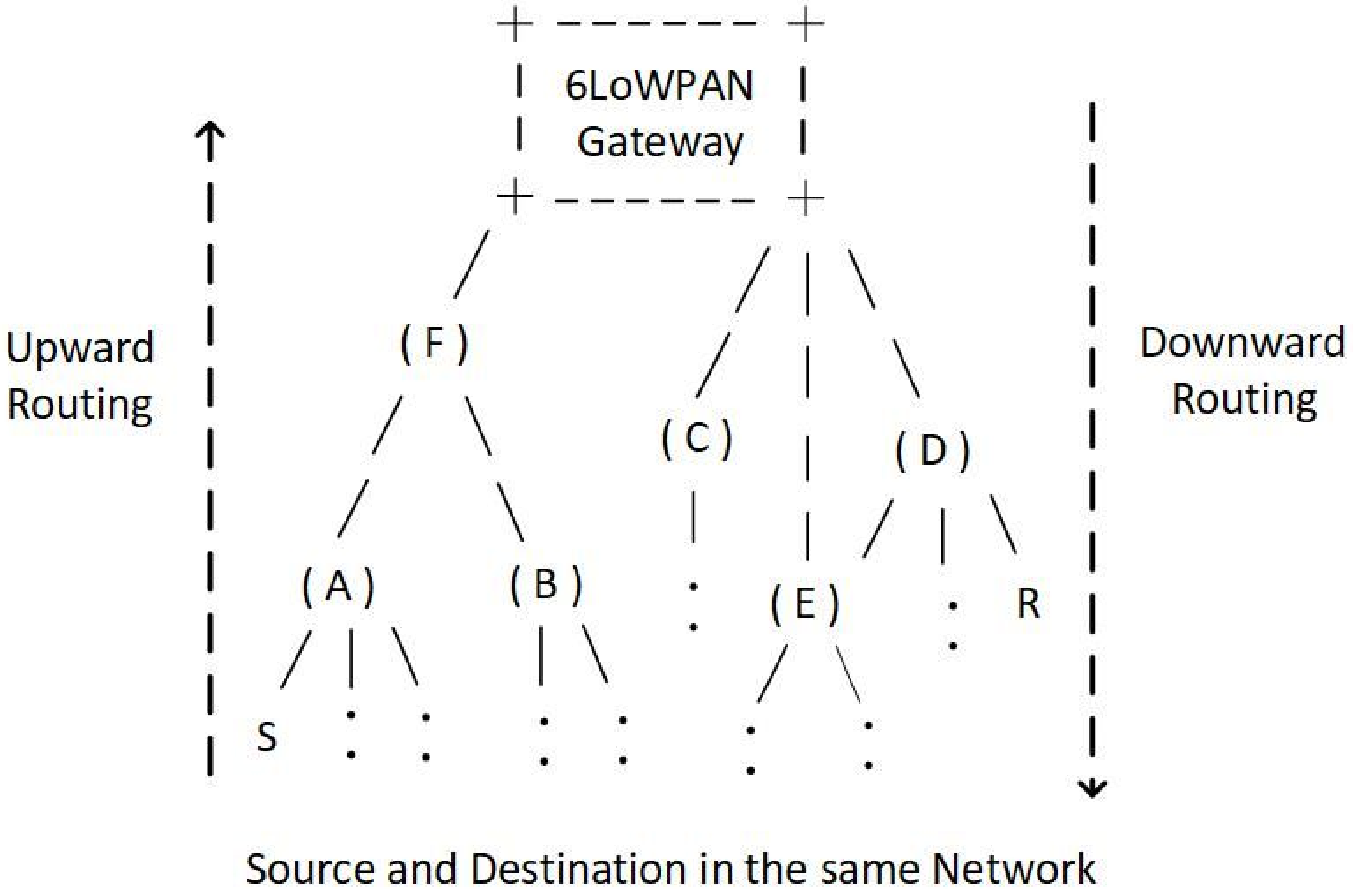

Figure 2

Data transmission in Point-to-Point(P2P) vehicular IoT Networks.

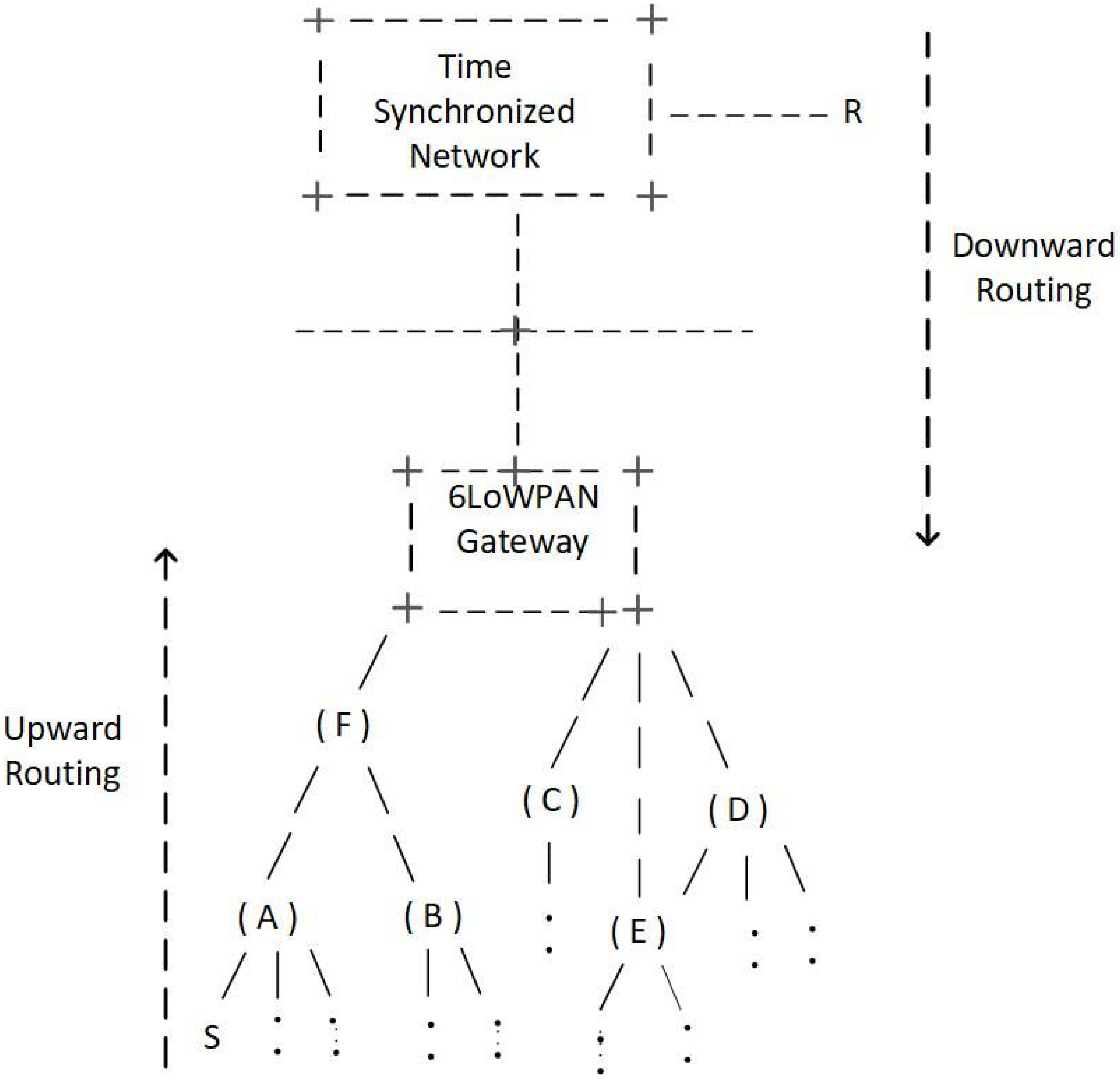

Figure 3

Data transmission in Multipoint to point (MP2P) and Point to Multipoint(P2MP) Vehicular IoT Networks.

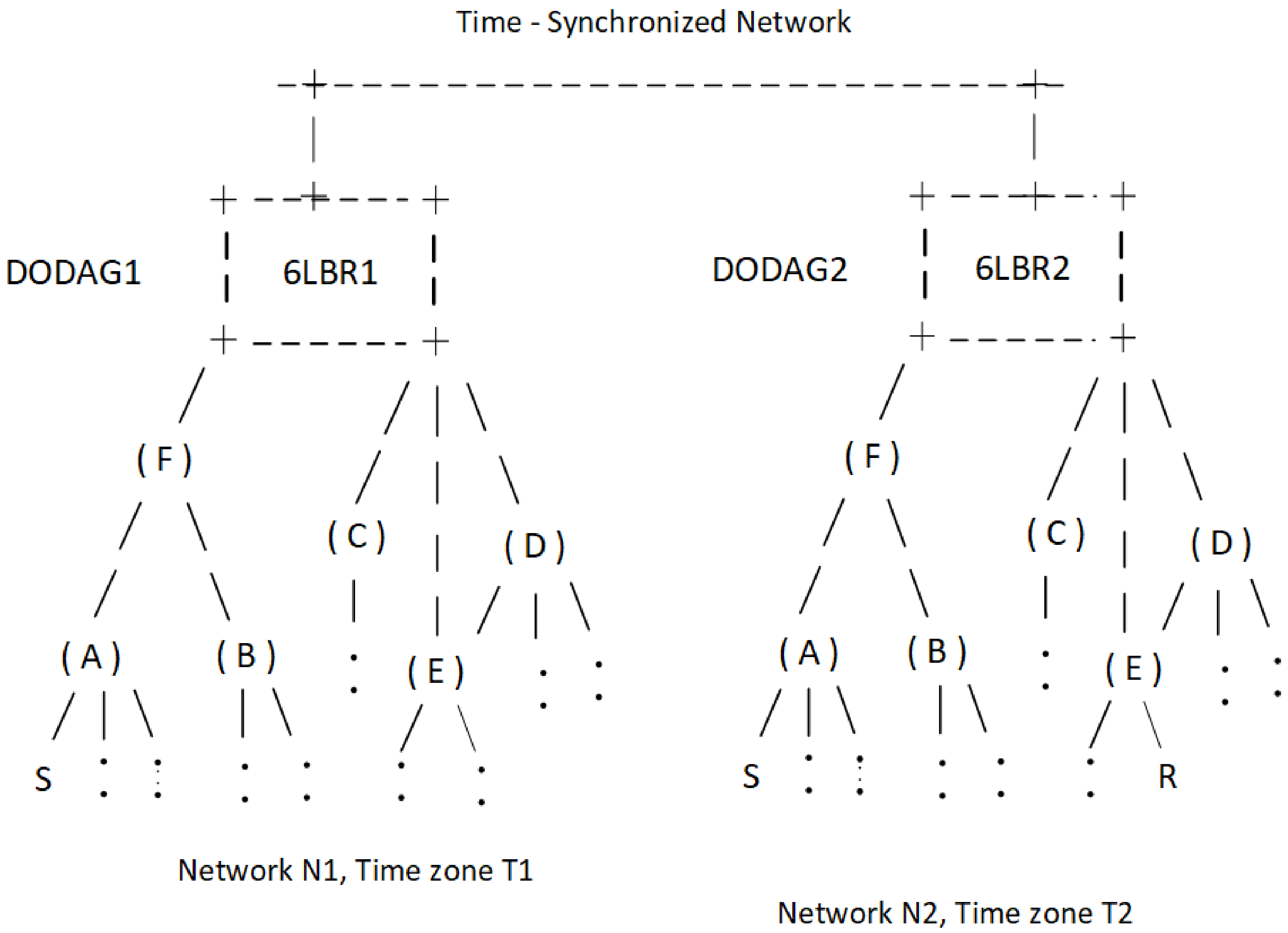

Figure 4

Data transmission in Point-to-Point traffic through internetworking.

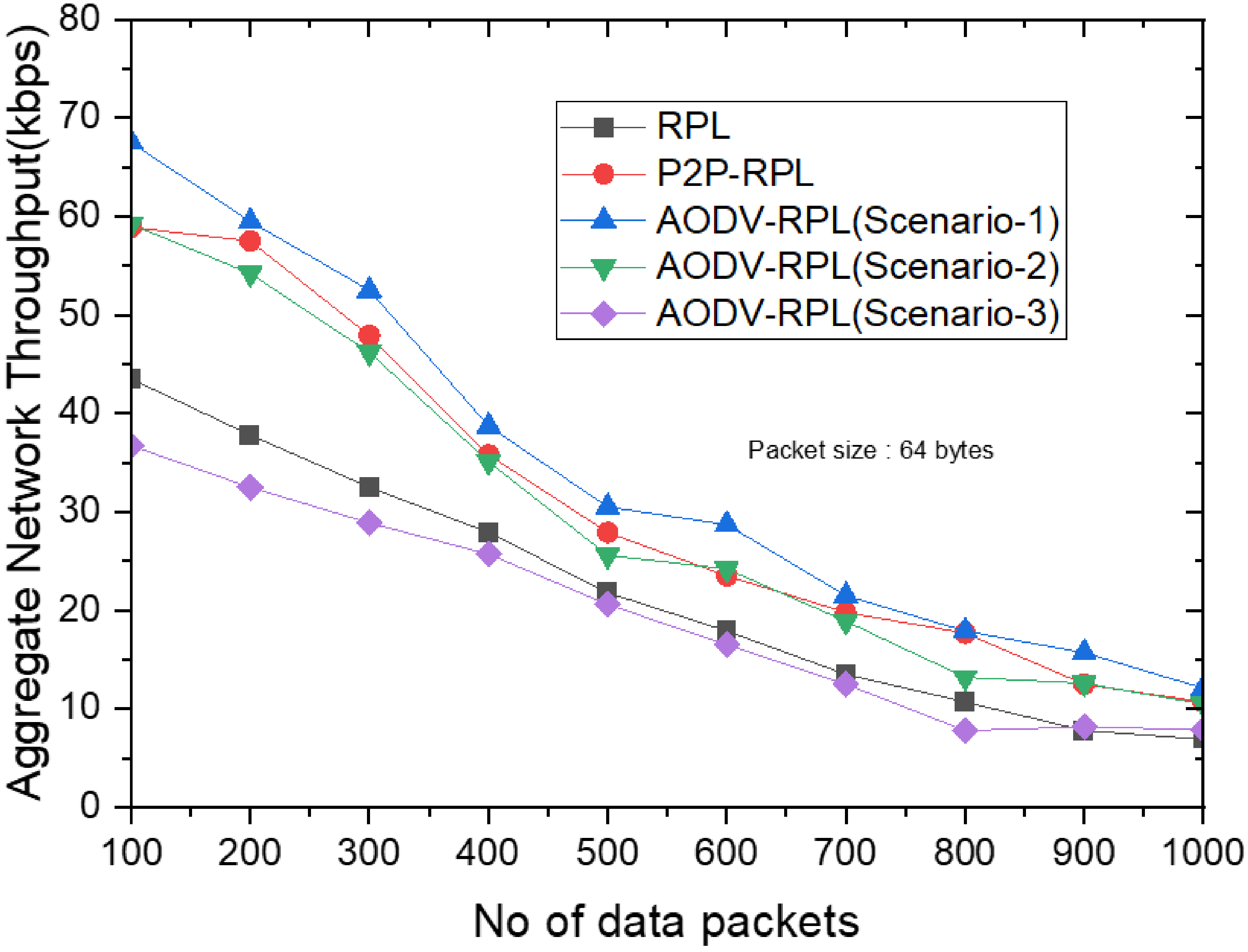

Figure 5

Aggregate Throughput with respect to data rate (64-byte data).

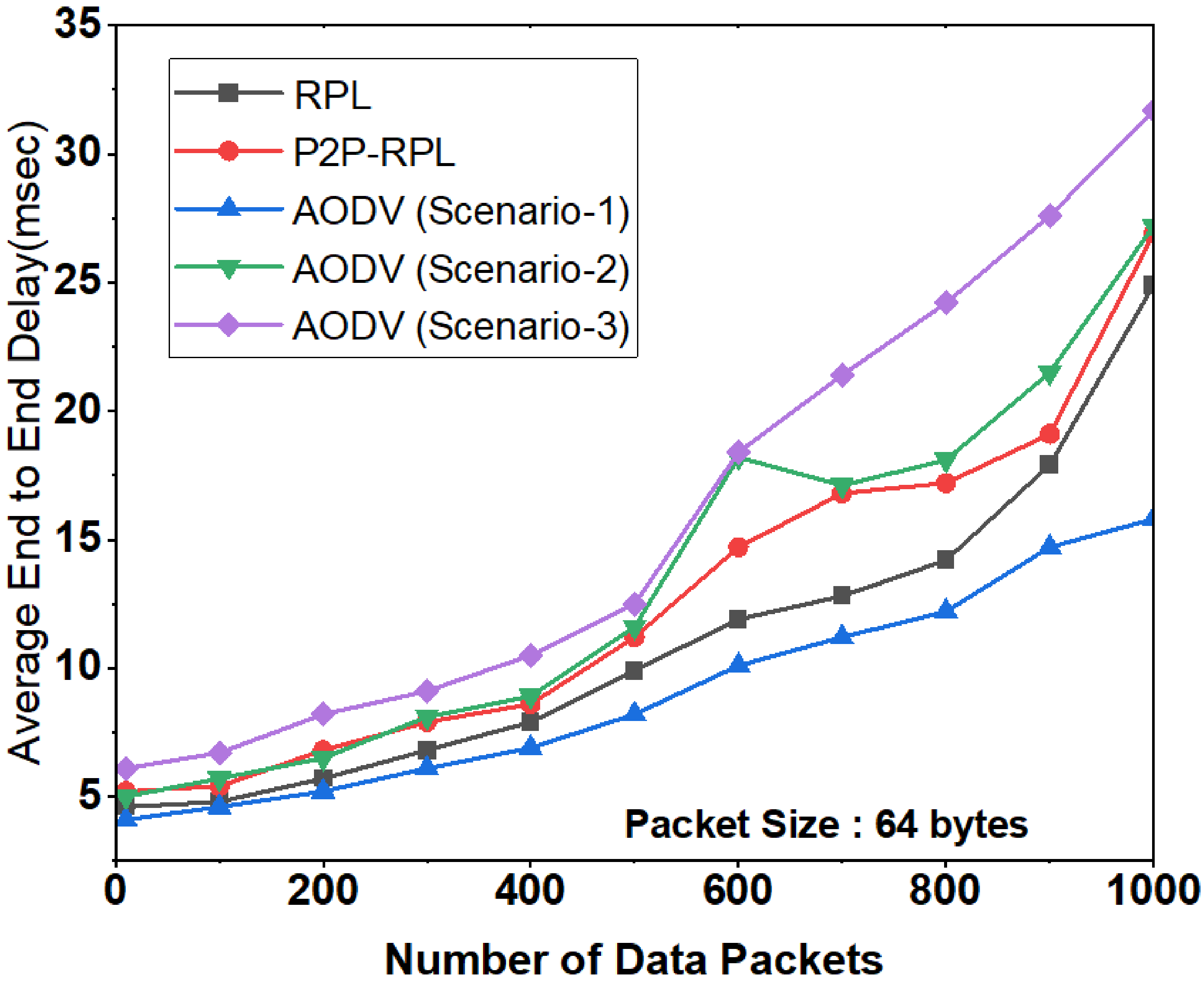

Figure 6

Average End-to-end delay with respect to data rate (64-byte data).

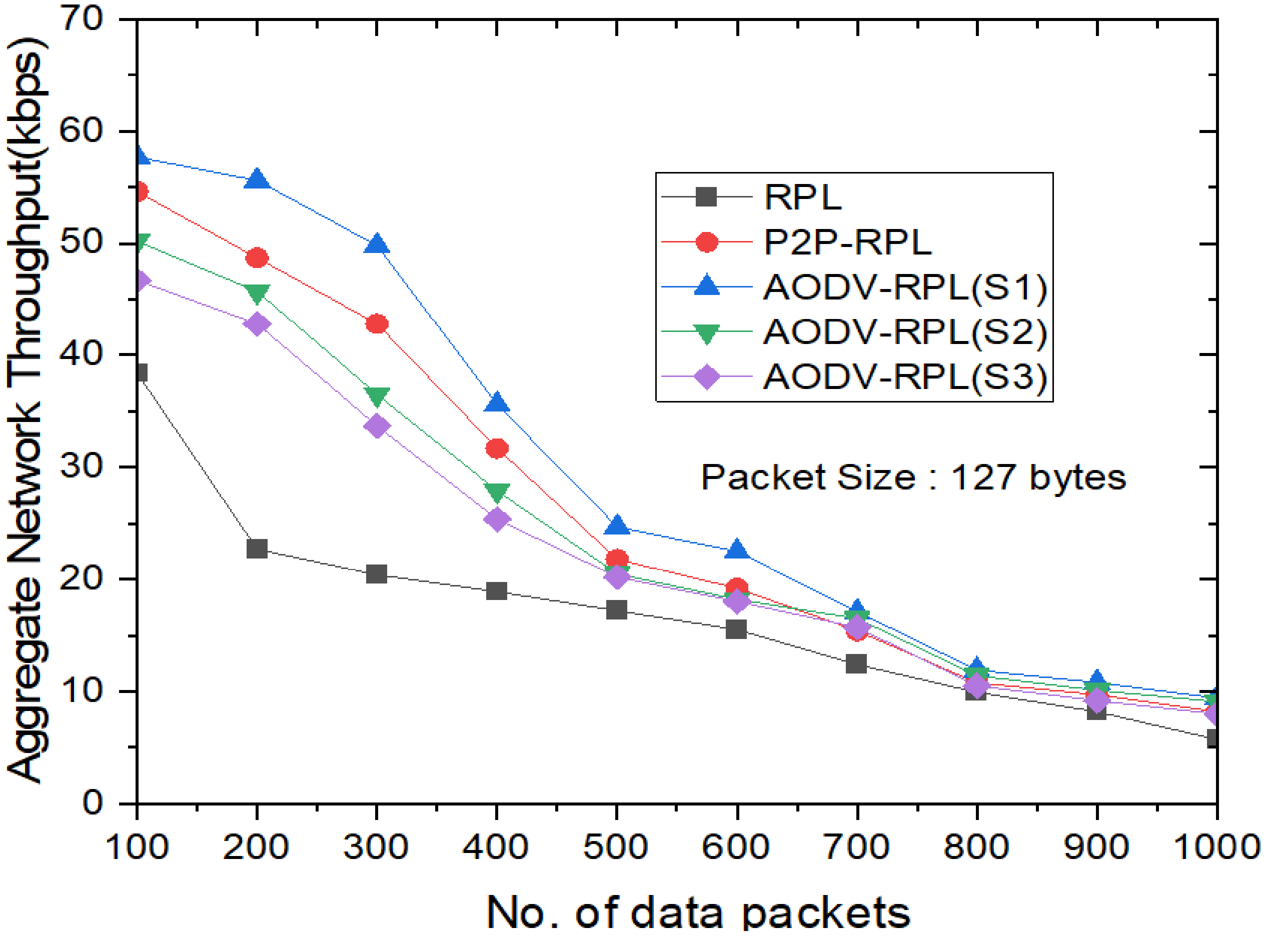

Figure 7

Aggregate Throughput with respect to data rate (127-byte data).

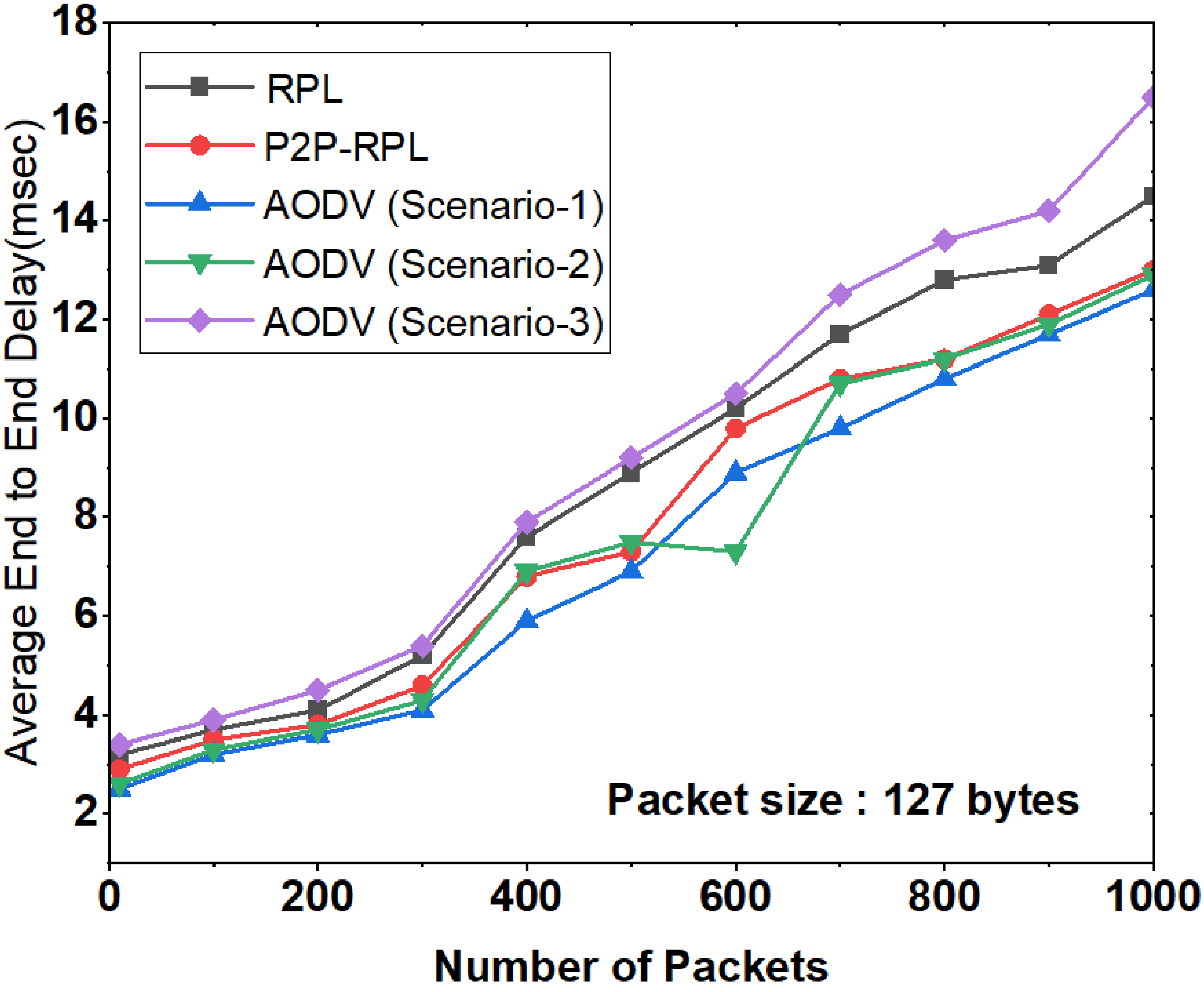

Figure 8

Average end-to-end delay with respect to data rate (127-byte data).

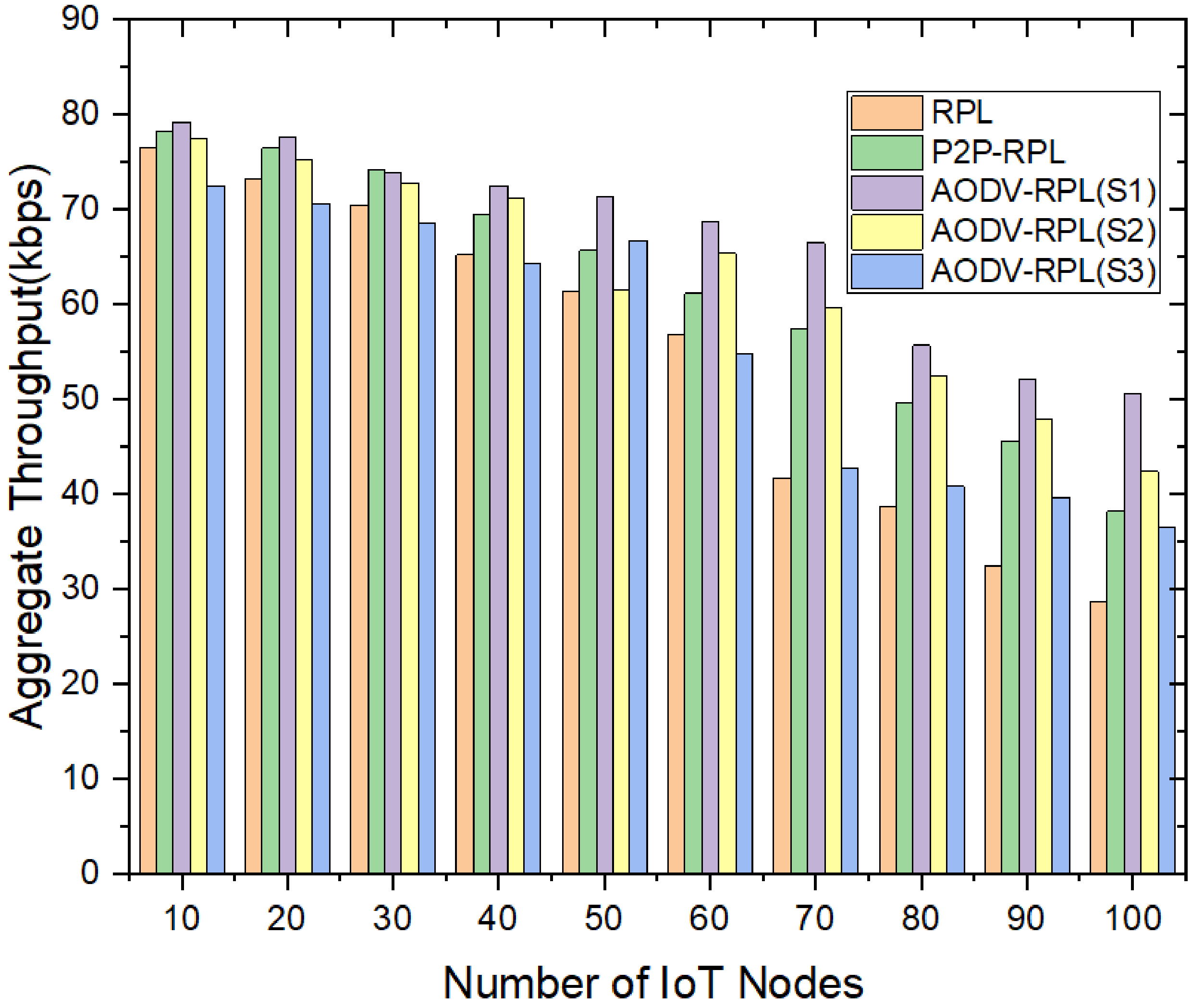

Figure 9

Aggregate Network Throughput with respect to Number of IoT nodes in the network.

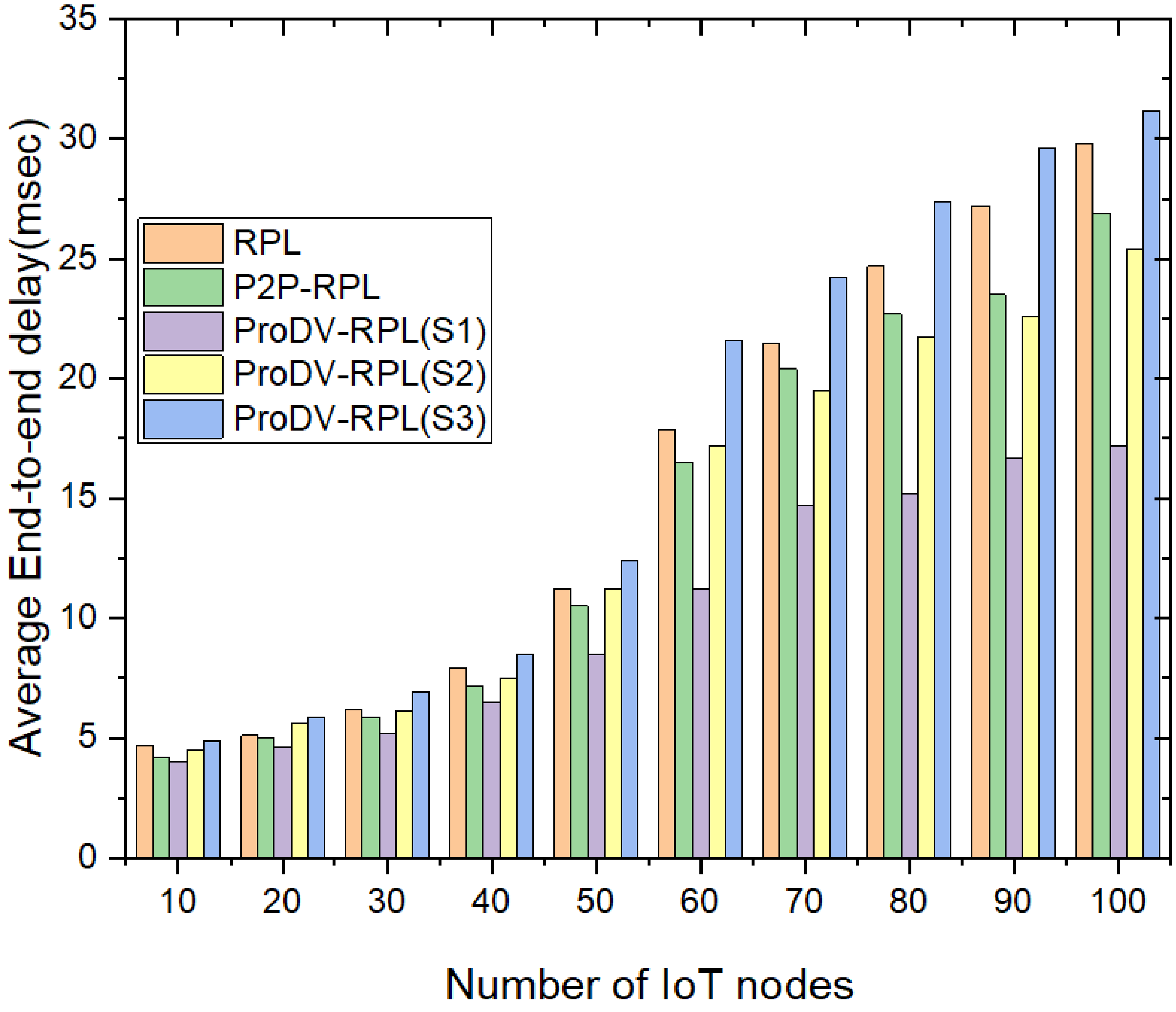

Figure 10

Average end-to-end delay with respect to Number of IoT nodes in the network