An RPL Performance Study under Different Independent Mobility Model Variants

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Abstract:

As of now the usage of mobility has been growing rapidly in every communication application, such as vehicle to vehicle communication (VANETs), military, medical care, manufacturing industries, etc. whatever it may be the usage of mobility has become an important part of that application. As the demand is increasing day by day, the only question is that how the mobility applications are dependent on IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL), because the IPv6 Routing Protocol enables the routers to exchange information about connected networks. This paper concentrate on appraising RPL performance under different independent mobility models. In this paper, the RPL performance is going to be evaluated in two different ways and they are static sink and sensor nodes, sink mobility and static sensor nodes. All these network strategies are going to be evaluated in the Cooja simulator. Here the sensor network consists of 10, 20, 30 nodes and one sink node respectively. Here the RPL performancein a network is going to be evaluated in terms of Packet Delivery Ratio (PDR) and the consumption of power.

***Keywords:** Mobility, RPL, LLN, PDR, Power Consumption, Sink Node, Sensor Node, IPv6, Cooja Simulator, Communication, VANET.*

I. INTRODUCTION

Generally, a Wireless Sensor Network (WSN) can be defined as the one which consists of static nodes that means the position is stationary where the nodes are in a static position. The utilisation of WSNs is escalate day by day and these low power networks can be implemented by using wireless sensor network that supports the Internet of Things (IoT) and the utilisation of mobility models is also being grown rapidly particularly on account of Vehicular Ad-hoc Networks (VANET) and by using any of the mobility models the technology can change the existing transport systemwith the help of safe interoperable wireless network communication among vehicles because the future is based on the communication of devices without the intervention of human [1, 2, 3, 4].

WSN is a combination of small sensor nodes having the capability of self-configured, to establish a communication network in Adhoc mode to work cooperatively with sensors for retrieving sensor readings and a mutual platform amongthe base station and themselves. The sensor nodes are more often resource-constrained due to their limited size, built wisely with minimum cost and less power consuming, perhaps it is important to utilize effectively with the background code and communication [8].

An IoT is a system is combined device with many components having the capability to data transfor without an physical contact of human and all other machines needed with instructions.Asensor network consists of static and sinks nodes in which the sensor nodes are utilised to deliver the sensor readings to the base station. The sensor nodes are very important for the exchange of information between sensor nodes and the sink node. Routing Protocol is the main reason for the transmission of routing information between the sensor and sink nodes and based on this route it will be able to find the short and optimal route for the transmission of packets. One of the well-known routing protocols in low power and Lossy networks is RPL [1, 8]. Based on this routing protocol the routing decisions are made; if the routing decisions that are made are not correct then a greater number of packets must be transmitted to the destination which increases the consumption of power and the PDR [8].

The challenging task for WSN's is with the other components in the segment for mobility, treated to be a frequent problem due to the thorough changes with the topology designed with the network and redundancy with the network performance due to mobility of nodes. Besides, a strategy like energy efficiency is followed within the design to follow static WSN's, in the case of mobile scenarios significant changes are not a good option in a practical environment. In concern with the additional problems like obstacles, errors in estimating and interventions are considered to be the potential threats for reduced reliability and efficiency of energy within the network. For instance, areas like industries, where the sensors are connected to workmen, equipment and all other desired goods need a trusted connection with the base station to have a complete track with the progress. It is desired to have the best location, routing decisions, protocols and nodes are strongly advised [6, 7, 8]. This paper will concentrate on RPL performance with the PDR and power consumption.

A. RPL

Internet Engineering Task Force (IETF) has designed RPL, it establishes a tree topology with no cycles which are called DODAG that stands for Destination Oriented Directed Acyclic Graph. It acts as a root and this graph is constructed by using an objective function [5, 9] that shows how the routing metric is determined. To exchange the data and to maintain the topology the RPL has four types of control messages and they are [1, 6, 8],

1. **DIO**: DIO stands for DODAG Information Object which is the principle source for controlling the routing information.
2. **DAO:** DAO stands for Destination Advertisement Object which is utilised to send the information of the destination node upwards along DODAG.
3. **DIS:** DIS stands for DODAG Information Solicitation which is utilised by the node when the node requires the DIO messages from neighbor nodes.
4. **DAO-ACK**: It is sent by the DAO recipient whenever it receives the DAO message.

The root gives information about the graph by using DIO messages. The neighbor nodes will receive the information then join and form a graph. These nodes maintain a route to the root node that's called as a parent node. The node gives information to the neighbors. This will enable neighbors to select their parents. In this, each node has a routing towards its parent and the leaf nodes can transmit their packets to the sink node by selecting an intermediate parent.

B. Linear Arrangement of nodes

In IoT Networks if nodes are arranged in linear order, each node contributes as aprocessor also as a router for transmitting the information between one device to another device in the network. If nodes in IoT Networks are arranged in linear order there is only one path from one node to another in a network [10].

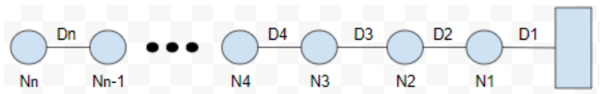

Fig 1: Linear / Grid arrangement of nodes

C. Random Arrangement of nodes

The random arrangement of nodes forms a topology that nodes are scattered from the air. Every node must send the data to the root that must be centered. There areseveral ways to reach from one node to another [10].

Fig 2: Random Arrangement of nodes

The real-time random arrangement of nodes is widely utilised compared to the linear arrangement because there areseveral ways to transmit the data to the root node.

Table 1: Research Issues in Network Topologies [10]

	Approach	Advantages	Disadvantages	Research Issues
1	Sensor nodes in Linear Order	Simple to implement for smaller applications.	Not efficient for larger applications.	Reducing power consumption.
		Low cost of implementation.	Power consumption of the node is more.	Efficient way of identifying failure nodes.
				Reducing delay in data transmission.
2	Sensor nodes in Random Order	Difficult to implement but efficient for a larger application.	Chance of retransmissions is more.	Measures to reduce retransmissions.
		Widely utilised in Real-time applications.	Difficult to cope up with frequent network changes.	Adaptability of nodes during regular changes in the network.
		Power consumption of nodes is less compared to linear.		

II. RELATED WORK

The performance of RPL has been evaluated under different simulation frameworks, scenarios, and applications. The RPL performance is going to be done under stationary mode where the nodes are in a not static position. To study the RPL performance several studies have done under different mobility conditions in the year 2011, in which they considered the nodes to be in dynamic position i.e. not stationary. There are many problems to move the nodes under mobility conditions and to overcome all these problems many researchers have done the work related to RPL to extend the RPL to support mobility [1, 8].

I.Wadhaj has studied the RPL performance under two different conditions they are mobile and static nodes, under this, he evaluated the performance of RPL as far as latency, consumption of power and PDR, based on all the conditions he evaluated he stated that the performance of static nodes isfar better than the mobile nodes. The evaluation also exposes that some number of sensor nodes have a high consumption of power while the other sensor nodes are in an isolation state [1].

H.Laamazi has studied the mobility effect to improve the RPL performance under three different scenarios: they are mobile nodes, fixed nodes, and multi-point technology. He considered

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two different types of mobility models and they are Random Waypoint Mobility Model (RWM) and Random Walk Model (RWM) and the results show that the loss of received packets has a direct impact of mobility [1].

L.B.Saad considered two different case studies one is mobile sinks and another one is Low Power Line Communication (PLC) to evaluate RPL. To increase the lifetime of a sensor network in Wireless Sensor Network they assessed the movement of sink nodes in Wireless Sensor Network and the results show the stimulating abilities for mobility.

Mobility Enhanced RPL (ME-RPL) was introduced by **I.Korbi**as an extension to support mobility and its main task is to identify the mobile nodes and to improve the RPL performance in terms of mobility, and they will give the status of mobility based upon the control messages given to mobile nodes. By using the ME-RPL technique a node can distinguish the static and mobile nodes present in the simulation and it can choose its parent as a static node preferred to the mobile node. ME-RPL is far better than RPL regarding packet delivery ratio and route stability, but it also has a drawback that it doesn't obey the rules provided in control messages for selecting the parent [1].

Another approach like VANET was done by **K.C.Lee** to study the RPL performance.In this model, RPL is mainly modeled for static nodes and it has a rank priority which is not updated frequently. According to these changes in topology, the results show slow reactivity.

To support the frequent changes in topology **B Tian** has proposed the use of geographical information. In this the algorithm that has been utilised, the trickle timer algorithm has been modified and they proposed a new strategy to adjust the node speed. And finally, the results show that the new strategy is better in terms of packet delivery ratio and consumption of power [1].

Although many mechanisms have been provided it's still becoming very difficult to find the parents as next-hop so to overcome this **O Gaddour** proposed Co-RPL as an extension to RPL based on the corona mechanism. And finally, this has proved that Co-RPL decreases the consumption of power, packet loss ratio and the end to end delay.

Recent studies were done on the enhancement of RPL in mobile arena areas such as, according to [1, 2, 4], RPL is clubbed with VANETs to identify the impacts of RPL parameters by a modified algorithm and a loop avoidance mechanism. In another study [3], Issues related to mobility using sinks were studied and adopted the Patten of control messages in parallel with the seed of mobile nodes. The study had differentiated with modified RPL and nodes of static and mobile. With [4, 7] WSN's assisting VANETs were tested to track the performance by using WSN's & VANET's.

Table 2: Advantages and disadvantages of Mobility Models [1, 2, 3, 4]

Mobility Models	**Advantages**	**Disadvantages**	**Research Issues**
. Random Walk Mobility Model	- This is the simple model to implement. - To consider all locations and node interactions it generates unpredictable	The movement patterns that are generated are unreal.	It should depend on previous velocity and direction of the node.
		It produces sudden and sharp turns.	By using state dependency of the nodes.

	movements by enabling the long running simulation.	In real applications no wrapping is observed.	Wrapped applications run slower.
Random Waypoint Mobility Model	As this model is simple this model is used most commonly.	It shows speed decay.	Introduce pause time.
		It has density wave.	There must be no accumulation of mass or energy.
		It can't achieve the steady state.	
Random Direction Mobility Model.	- The main advantage of this model is that it overcomes the density wave problem. - It does the Uniform distribution of the chosen routes.	The movement patterns that are generated are unreal.	It should depend on previous velocity and direction of the node.
		The distances between mobile nodes are much higher that leads to incorrect results for evaluation of routing protocols.	It should uses persistent storage to avoid the loss of data as the transmit power increases.

Even though many strategies have been evaluated they still lack in terms of RPL performance under mobility conditions. Many studies have been conducted and these studies consider either sensor nodes or sink nodes in mobile, without considering both in mobile or in a static position and to avoid these situations the studies have been extended to include static sensor and mobile sink nodes.

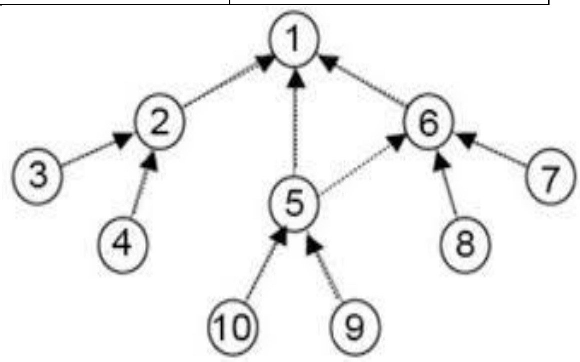

Fig 3:Tree Topology for RPL

A. SIMULATION CONFIGURATION

The simulation tool that has been selected is the Cooja simulator. The Cooja simulator is an adaptive java simulator for running the Contiki OS. By default, Cooja doesn't support mobility to support mobility cooja's mobility plug-in must be enabled. Cooja can work on various levels: for example, machine code instruction level network level and operating system level it can work on various platforms such as Sky, TelsoB, native and so on. It incorporates numerous situations and it is an open-source code that can be modified by our application.

Table 3: Simulation Configuration

Settings	**Value**
Model of propagation	UDGM with loss of distance
Type of mote	Sky mote
Tx ratio	100%
Rx range	30m, 60m, 100m
Time of simulation	1200000ms
Total nodes	10,20 and 30
Type of topology	Grid, Random
Squared area	100m*100m
Objective functions	MRHOF [5, 9]
Mobility models	RWPM, RDM, RWM.

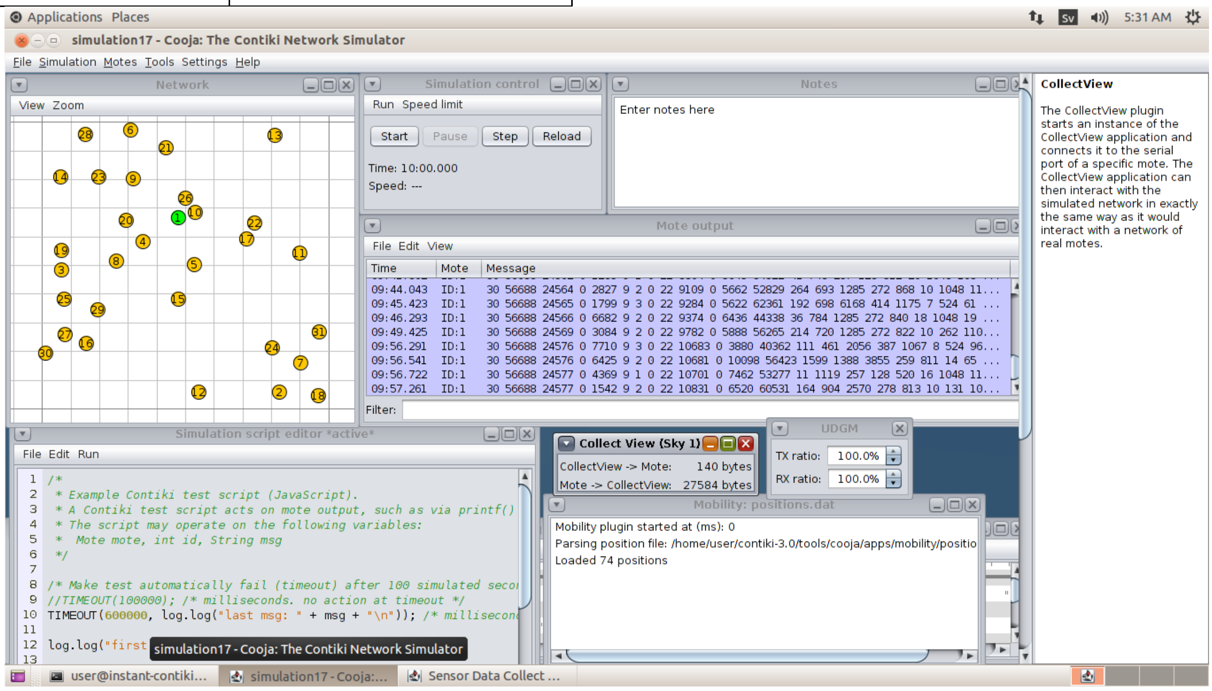

Fig 4: Network Configuration in Cooja

B. Packet Delivery Ratio

PDR is based on several data packets successfully delivered from nodes to the root node of the IoT Network by many data packets originated by the nodes over a network [8].

$$PDR = \frac{\text{No.of packets delivered to root node}}{\text{No.of packets originated from a source node}} \quad \dots (1)$$

PDR can be calculated based on the lost packets and the packets generated in the network. With the help of the PDR, one can calculate the efficiency of an IoT network.

C. Power Consumption

IoTN nodes are sensors that are having less processing power and low power consumption nodes. As power consumption plays an important role in IoTN. Generally, several nodes increases, the load on each node increases, as a result, it consumes more power to transmit information from one node to another node.

Power consumption of nodes is observed byvarying the number of nodes and receiving the capacity of nodes in a network [8]. For observing the power consumption of nodes parameters like LPM, listen to power, transmit power and CPU power are considered which are resulted from the simulation.

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III. EXPERIMENTAL ANALYSIS

In mobility, the nodes are considered three different conditions Rx30, Rx60 Rx100 in Random Waypoint Model. The mobility is tested with three different types of nodes 10, 20 and 30. Each one of these types contains combination of sensor nodes and a sink node.Sensor nodes are in static nature with in the simulation and for dynamic conditions sink node is placed to trak the position from one place to another. In this study, three major types of mobility models were considered to evauate the response of the sensor nodes with random in walk, direction and waypoint. Each of these mobility models is considered under different conditions to increase the PDR and Average power that will help to improve the performance of RPL.

Table 4 consists of different types of mobility models Random Waypoint Mobility Model, Random Walk Model, Random Direction Model in which three different Rx ratios are considered and the ratios are Rx30, Rx60 and Rx100. Each of these ratios has been taken under a different number of nodes 10, 20 and 30 and calculated the Packet Delivery Ratio.

Similarly, Table 5 consists of different mobility models under different ratios and here we calculated the average power based on lost and received packets.

Table 4: PDR under different scenarios

S.No	Model		Rx Ratio	PDR (for set of dissimilar quantity of nodes in percentage)		
				10	20	30
1	Random Waypoint Model	Grid	Rx 30	90.3	96.2	95.2
			Rx 60	94	97	94.1
			Rx 100	95.6	94.6	96.5
		Random	Rx 30	90.2	89.5	87.2
			Rx 60	84.2	96.5	88
			Rx 100	86	93.8	93.1
2	Random Walk Model	Grid	Rx 30	85.2	88	90
			Rx 60	89.1	91	87.5
			Rx 100	88.5	90.1	92.4
		Random	Rx 30	88	85.1	83.4
			Rx 60	82.1	90.8	85
			Rx 100	83	90.2	91.2
3	Random Direction Model	Grid	Rx 30	90.1	89.5	96
			Rx 60	88.4	89	90.5
			Rx 100	93.8	86	95.3
		Random	Rx 30	85.1	88	93.2
			Rx 60	83.4	90.2	92.1
			Rx 100	87.2	85.1	95.4

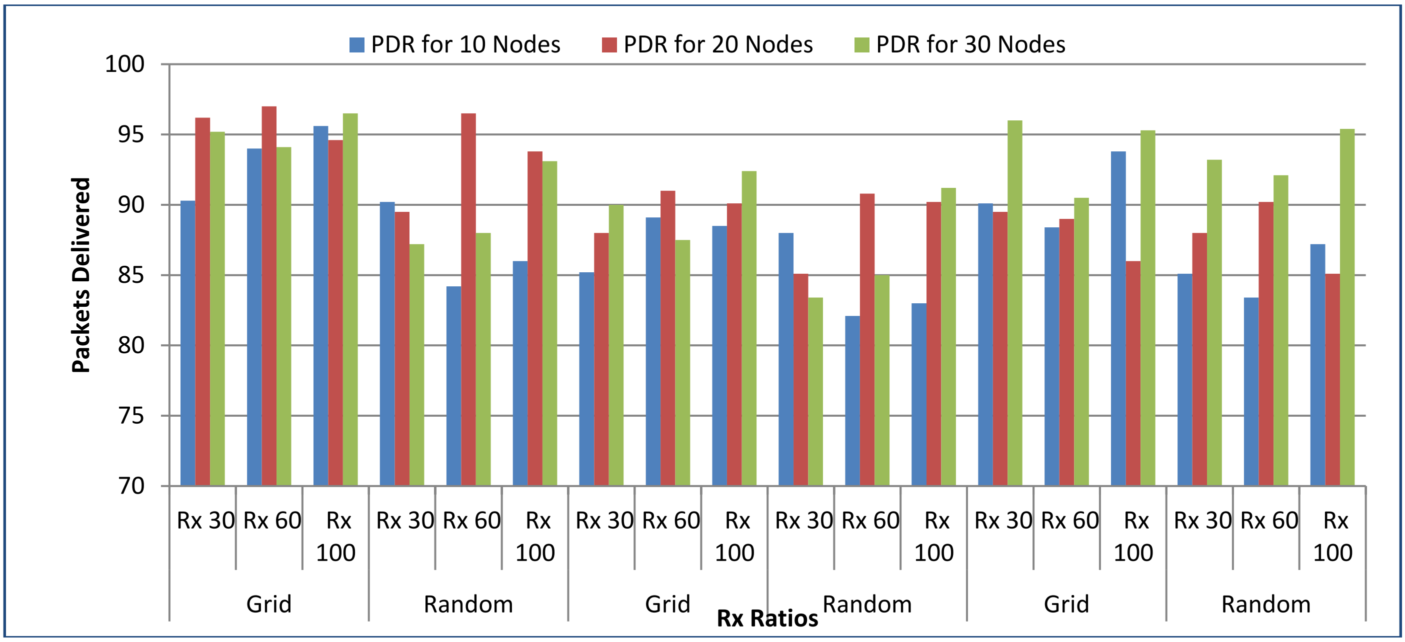

Fig 5: PDR under different scenarios

Table 5: Average Power consumption under different scenarios

S.No	Model		Rx Ratio	Average Power Consumption		
				10	20	30
1	Random Waypoint Model (RWPM)	Grid	Rx 30	1.919	1.719	2.321
			Rx 60	1.790	1.737	2.451
			Rx 100	1.411	1.531	2.119
		Random	Rx 30	1.565	2.309	3.248
			Rx 60	1.586	1.595	2.404
			Rx 100	1.587	1.529	2.250
2	Random Walk Model(RWM)	Grid	Rx 30	1.515	1.652	2.134
			Rx 60	1.453	1.654	2.345
			Rx 100	1.654	1.213	2.001
		Random	Rx 30	1.435	1.987	2.301
			Rx 60	1.423	1.234	2.202
			Rx 100	1.342	1.456	2.004
3	Random Direction Model (RDM)	Grid	Rx 30	1.654	1.345	2.456
			Rx 60	1.321	1.654	2.321
			Rx 100	1.789	1.432	2.564
		Random	Rx 30	1.143	1.436	2.213
			Rx 60	1.234	1.644	2.453
			Rx 100	1.876	1.889	2.876

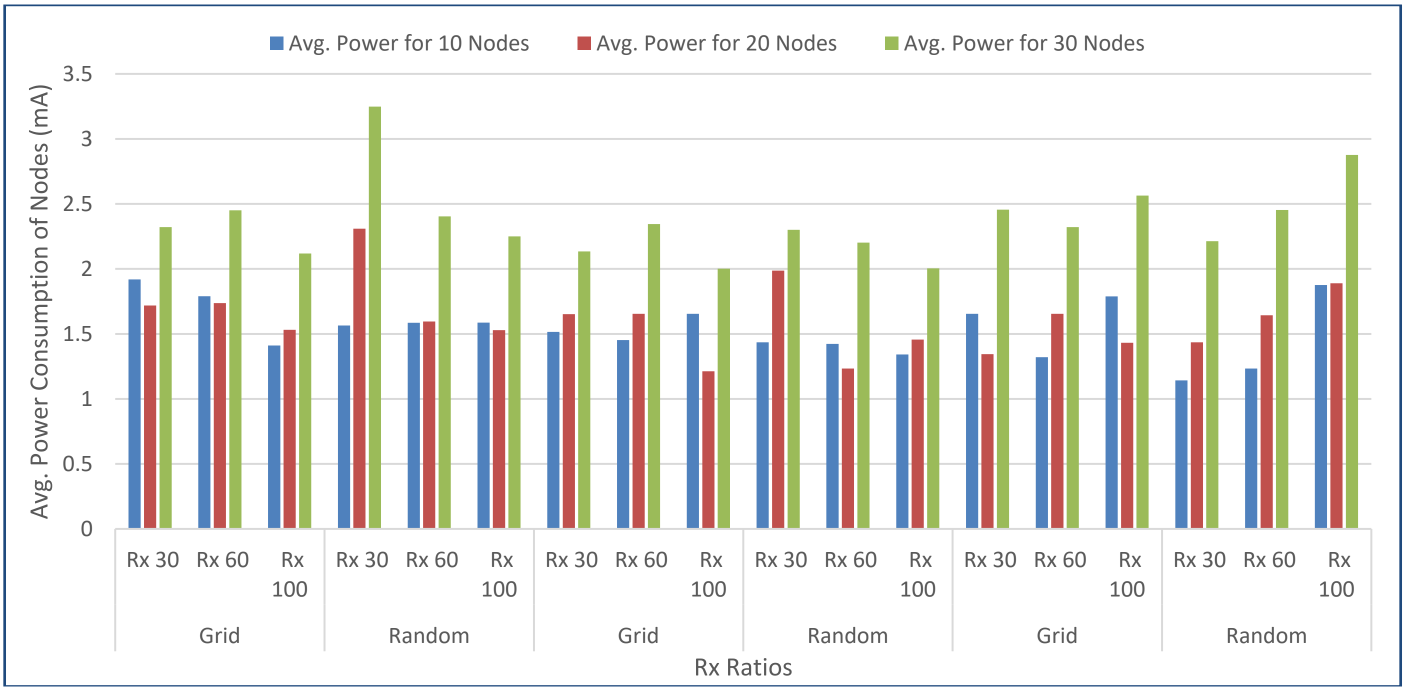

Fig 6: Average Power Consumption of Nodes in a Network

IV. CONCLUSION

In connection with mobility in WSN's, LLN's are to be compromised with efficiency and complex in nature while setup, because of challenges within the sequence. It is observed with LLN's that the communication with RPL & LLN's is not compatible withoriginal design and needs with special support to enhance mobility. Probably the major disadvantage of not utilizing in many applications. This paper is going to analyze and evaluate the RPL performance under mobility in two different conditions and they are: static sink and sensor node, sink mobility and static sensor node. These two conditions have been assessed to observe the behavior of nodes concerning power consumption and PDR. In the first situation, the topology is fixed, mobility models and the transmission ranges are changed, and in the subsequent situation, the transmission ranges, the topology,and mobility models are changed. By observing the arrangement of nodes in a network with different objective functions, different mobility modelsand different receiving capacities with an increase in receiving capacity PDR also increased. But in OF0 the difference between PDR is less compared to MRHOF**.** Regarding the power consumption of nodes in a network, OF0 is efficient than MRHOF.

RWPM is better as it introduces pause time between nodes in the simulation area and it also acts as a foundation for many different models. The PDR and average power consumption in the Random Waypoint Mobility model are better for less number of nodes but even after comparison. In the RWPM, speed decay problem is encountered by increasing the duration of the simulation the average speed of the mobile node decreases and this drawback is overcome by RDM Model. Hence the PDR and normal power consumption in the RDM model is better when the network contains more number of nodes.

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