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Modified S-MAC Protocol for Wireless Sensor Network

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Abstract —*Network comprises a vital importance in today`s world. Communication was earlier were static in terms of end nodes. But with growing demand of mobility, static network in fractures are losing their importance. On the other hand, Wireless Sensor Network is growing its importance. Still it has its own challenges to be tackled. Various problems of mobility, sustainability, throughput, energy consumptions etc. are still to be overcome. In these kinds of adverse scenarios, medium access or channel allocation is one of the major problems to be solved. Medium Access Control protocols are working pretty well in terms of Wireless Sensor Network still can be modified to get the best results. This paper is approach towards explaining and further proving Modified S-MAC, working as a collaborative approach with two methods. Also comparison between three MAC protocols are made in this paper and further the best one is judge.*

***Keywords**-S-MAC, IEEE 802.11, Modified S-MAC, WSN, MAC Layer, NS-2*

I. INTRODUCTION

Wireless Sensor Network (WSN) has its own importance, prominence and usability in networking world. WSN can be defined as ad-hoc network working under a remote scenario/field, where mobile nodes are sensing, computing and further communicating with each other and even further taking decisions to suitably deliver the data between nodes and still sustaining itself in the communication. But unlike every technology has its own pros and cons, WSN also has its own pros and cons. Medium sharing or Medium allocation is a major challenge to be tackled in WSN. Because in remote scenarios of ad-hoc fashion nodes may enter or leave the network at any time, and the topology may change. Still various researches have tackled these problems up to some extends and still can be improved.

WSN has its own working manner because each node works individually. There are few basic components of WSN, Micro-controller, Trans-receiver, Memory unit, Sensors and battery pack. All these components combine to form WSN nodes. The infrastructure of WSN can easily be understood with the help of its architecture. Unlike International Standard Organization - Open Standard Interface (ISO-OSI), WSN Layered Architecture is quite simpler because here only three layers play the important role. Physical layer remains as it is where as data link layer acts as MAC layer here, which is again bifurcated into MAC sub-layer and Logical Link Control (LLC) sub-layer. Whereas the entire upper layer layers are submerged and can be utilized as per the scenarios. It can easily be understood with the help of Figure 1 [1].

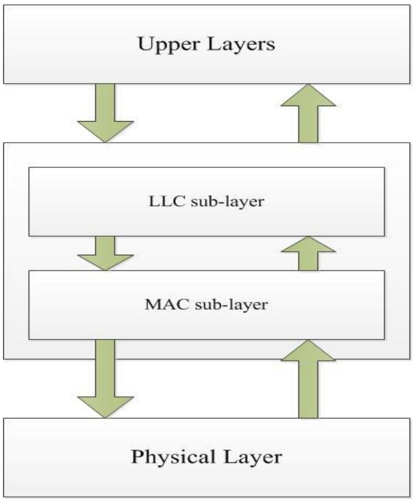

Figure . WSN Layered Architecture

II. S-MAC

Sensor - Medium Access Control (S-MAC) protocol was designed with a motivation of energy reduction caused by various parameters like collision, idle listening, control overhead and overhearing. The approach is to achieve energy efficiency by stability and sustainability. It was first proposed by Wei Ye, John Heiedmann and Deborah Estrin at IEEE

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INFOCOM, 2002 [2]. In WSN scenario, packets can send and received in various fashions. It can be a Constant Bit Rate (CBR) or Variable Bit Rate (VBR). But here it has to be processed also, or some computation depending upon that data is to be done at intermediate nodes also and further some decision is also to be taken. So generally store-and-forward scheme for packet sharing becomes necessary in these kind of scenarios [3]. S-MAC has few of its own schemes to tackle with all these listed below:

1.1. Periodic Sleep and Wake-up

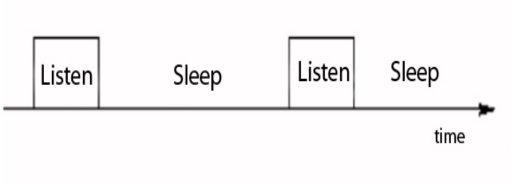

Figure . Fixed Duty Cycle

Periodic sleep and wake-up can be considered as the most basic property of S-MAC. S-MAC totally works upon this simple mechanism. The goal behind deploying a mechanism which follows a duty cycle is reducing energy consumption. S-MAC does this by making nodes sleep or more generally can be termed as switching off the radio. This process of turning off is done periodically. Each node has to sleep for certain interval of time and then wake-up for fixed interval and can receive and send packets in that listening phase. The node has a self-timer mechanism which recalls it whenever its wake-up time come. One listens and sleep state combine to form a frame. Multiples of such frame from stating of the communication till the end, combines to form a duty cycle shown in Figure 2 [2].

1.2. Collision Avoidance

When multiple neighbors talks with each other at same time either by sending or receiving packets during listening phase, or either during contention time, it result into packet collision. S-MAC utilizes two way carrier sensing, virtual and physical. Also it uses RTS/CTS mechanism to avoid hidden terminal problem. Hidden terminal is a problem where if two adjacent nodes are communicating and neighbor of either of it is not aware about the communication of other two nodes and further sends data resulting in collision of packets.

1.3. Adaptive Listening

The phenomena of periodic listen and sleep reduces idle listening. Also sensing event indeed happens, it is desirable that sensing data can be passed through network, with considerable less delay. And due to all these type of scenarios and fixed duty cycle followed by S-MAC, nodes remains in low-duty-cycle mode more and active lesser. The phenomena says that even after completion of Listen phase, if the node encounters with either of RTS or CTS, it may happen that neighboring node is still communicating with the current node. So if the node is next-hope node, the neighboring is able to immediately pass data to instead of waiting for its scheduled listen time. If the node does not receive anything during adaptive time, it goes back to sleep state [4].

III. RELATED WORK

Various approaches exist leading towards modification or improvisation of MAC layer properties. Few of which undertaken for survey are discussed below.

Improved S-MAC is an approach towards improving duty cycle. Basic operations working as principles of S-MAC, Periodic Listen and Sleep, Collision Avoidance and Adaptive listening are elaborate as earlier. The approach of S-MAC allows the nodes to start transmitting after complete arrival of CTS. This approach results in unnecessary delay. The improved S-MAC lets the nodes to initialize their transmission just after successful reception of CTS packet. As a result of which authors were able to achieve 5% decrease in total energy consumption in high traffic load consumption over standard S-MAC [4].

Another approach is of TDMA-W. Once this process is completed, data frame sharing is done with TDMA-W protocol. Nodes listen in their W-slots assigned. A Incoming counter, initially assigned with some positive value is initialized. This counter value is kept on decreasing as per the data frame is arrived up to node from some other sender node. At a instance when the counter value becomes zero or even negative, the node stop listening further from corresponding S-slot of the cycle. Similarly an Outgoing counter is also initialized with positive value, If no frame is send in corresponding TDMA-W cycle, its value is decremented. It is reset to starting value with each successful transmission. When a node has data to send to a particular node, it checks the value of the corresponding Outgoing Counter. If the counter is less than or equal to zero, the node is considered to be in sleep state in the S-Slot of the sender, and a wakeup message is sent to the node during its corresponding W-Slot. The sender starts sending data to the node during its S-Slot from the next TDMA-W frame. If the counter is positive, a wakeup message is not sent and the sender transmits data in its S-Slot. On receiving a wakeup message, the node turns on its radio in the S-Slot of the sender in the next TDMA-W frame. If more than one wakeup messages are received in a single TDMA-W frame, a collision occurs and the node starts listening to all its neighbors from the next frame in order to identify the senders [5].

A-MAC is one more approach towards this level of modification. The full form of AMAC is Adaptive Medium Access Control protocol. Unlike other approaches, AMAC also works in aspect of modification of duty cycle of standard S-MAC. Duty cycle of inverse powers of 2 is used for maintaining common periods. An AMAC node informs neighboring nodes of changes which allows neighboring nodes to properly schedule communication with the node. Convergence of node schedules is on the order of minutes. This process continues throughout the operation of the network. The duty cycle bounds the mechanism in terms of sleeping and wakeup schedule. This mainly results into constrained traffic scenario, which is preferably good in some aspects. Variable traffic conditions are maintained by a variable called currentusage. It is affected by the changes in listen period. A used slot means data was either sent or received. Its value and duty cycle value are described by the author. When sensitivity level is one, AMAC behaves like S-MAC and towards zero it is more sensitive to changes. Node synchronization can be done by sending or by receiving RTS/CTS. The strategy says that if the buffer gets full above some limit, it may undergo dumping process. It is set to 20% and 70% priorly. In packet dump mode, a node only acts as a receiver during adjacent slots. These are slots not synchronized with the next slowest duty cycle [6].

One more method exists called LO-MAC. LO-MAC (Low Overhead Medium Access Control) protocol improves S-MAC by decreasing control energy consumption and thus increases network lifetime and resolves early exhausting problem with end nodes. Unlike S-MAC prior assumption for node synchronization is, LO-MAC has uniform duty cycle followed by all nodes. Initially during node synchronization phase, every node keeps on listening the SYNC packets send by cluster head or sink node. Once it is received, all the nodes adjust their time relative to the announced one. Until timer doesn’t expire the nodes keep on working accordingly. The periodic sleep and wakeup schedule is continuously repeated until a fixed prior value is not reached for number of cycles. The process of clock drifting is beginning once when new synchronization period is scheduled. At that moment of time nodes will wake up from sleep and turn into synchronization state to receive SYNC packet from sink node. In this schedule period, nodes sleep time is shorter because they spend some time on receiving SYNC node, and is called as short-sleeptime. Synchronization time plus short-sleeptime equals long-sleeptime. The schedule consists of long-sleeptime and datatime is named schedule1. Schedule1 or one schedule2 is called a schedule period. Suppose the sink node broadcast SYNC packet every K schedule periods. At beginning, nodes stay at listening state until they receive SYNC packets from sink node, and extract the time to next sleep time from the packet, then get into sleep state. Passing through the first sleep state, nodes enter data time sate. When the data time is over, nodes turn into schedule1 again and keep a number of periodic listen and sleep. When the number of schedule1 reaches K-1, nodes get into schedule2, and at the beginning of schedule2s synctime nodes wake up from sleep to revive SYNC packets sent from the sink node. When schedule2 is over, nodes enter schedule1 again, then after K-1 schedule1 node turn into schedule2 once more and recycle in succession. The number of K is set according to the application and the sensor nodes time drift [7].

IV. MODIFIED S-MAC

The proposed technique is amalgamation of existing standard S-MAC and some of the approaches working in a direction to modify and improve S-MAC in terms of its duty cycle. There are few existing as well as modified techniques which makes S-MAC unique in comparison to other techniques

4.1. Dynamic Property

Dynamic S-MAC is a protocol that dynamically changes the entire frame size by modifying the frame [8]. For achieving that here a new variable is introduced, flag. The function of this flag variable is to decide whether the period should be active or sleep state. This toggling of Sleep or Wake-up state by flag variable is shown in Figure 3 [8].

For that here two rules are defined as follows:

1. If the flag value is 0 in the prior active interval, the next active interval has a sleeping schedule.

2. If the flag value is 1 in the prior active interval, the next active interval has an active schedule.

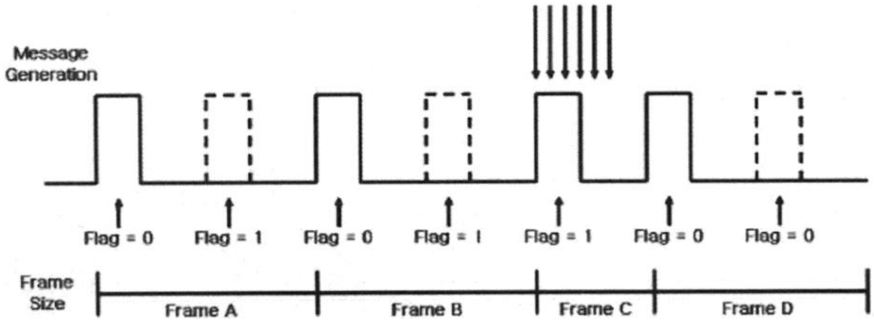

Figure . Dynamic S-MAC

4.2. Synchronization

So by these rules the toggling of flag values is done. But still reducing latency is a problem. So for that two more rules are used to reduce or increase frame size dynamically. The node sends SYNC packet to its neighbor only when if they contain schedule with flag value 1.

Following are rules and one can visualize it from Figure 4 [8].

1. If we have flag value 0 in the active period we will double frame size.

2. If we have flag value 1 in sleeping period we will half the frame size.

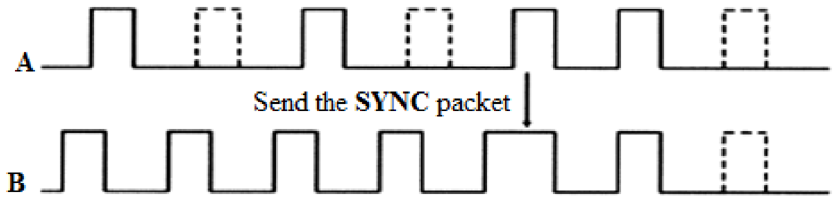

Figure . Dynamic S-MAC Synchronization

4.3. Selective Intermediate Node (SIN)

One of the major problem while node discovery and channel allocation in WSN faced by MAC approaches is common coverage. SIN reduces idle listening of intermediate shared nodes, considering the fact that they are necessary for inter-cluster communication. It also helps in energy conservation. In SIN, when a sensor node receives a schedule, it checks its schedule status and initializes following steps [9]:

1. If node is not following any schedule, it adjusts its wake up and sleep schedule to that of the announced one.
2. If already following some schedule, it sends a unicast message for asking permission to follow announced one. Upon receiving such requests, the announcing node replies to a selective number of nodes acknowledge them to adopt the new schedule in addition to their already assigned one. Only the nodes who received acknowledgement will follow both the schedules.

The selection of nodes in above process is done by First Come First Served fashion (FCFS). SIN is shown in Figure 5 [9].

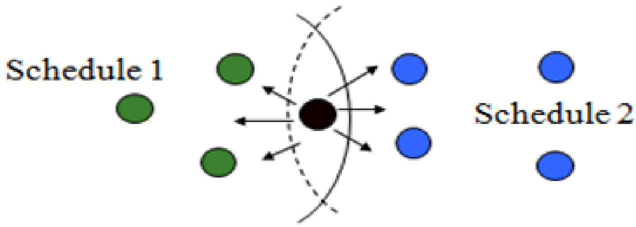

Figure . Selective Intermediate Node

V. SIMULATION AND ANALYSIS

5.1. Simulation Configurations

NS-2 (Network Simulator Version 2.34) by LBNL (Lawrence Berkeley National Laboratory) is used for simulation purpose. Versatile MAC level schemes can be simulated along with various routing can be implemented across this tool. Also a vivid simulation topology can be generated as per desired scenario with the help of NS-2 [10].

In implementation scenario, 42 different nodes where no fixed topology is assigned still they are initially arranged in circular fashion. Here three different MAC schemes IEEE 802.11, S-MAC and Modified S-MAC are applied across the same setup. The scenario is deployed in field of 2500*2500 dimensions with Omni-directional antena for 100 seconds. All in all, in the scenario, either of the protocol is applied under the same topology. Further the detailed description of it given in Table 1.

Table . Configuration Parameters

Description	Scenario
Simulator	NS2-2.34
Simulation Time	100 s
Data Link Layer	SMAC / IEEE 802.11 / Modified S-MAC
Routing Protocol	AODV / DSDV
No. of nodes	42
Propagation	Two way ground
Dimensions	2500 * 2500
Packets in ifq	50
Antenna Type	Omnidirectional
Node Motion	Dynamic

The scenario is working with AODV (Ad-hoc On-Demand Distance Vector Routing) DSDV (Destination-Sequenced Distance Vector Routing) under IEEE 802.11, S-MAC and Modified S-MAC as data link layer implementation. Besides the scenario is having some randomization in terms by providing node mobility. Node 0, 18, 31, 32, 25, 13 and 14 are provided mobility and they leave their current state at certain fixed time. Besides this the exchange process of cluster head between node 0 and 18 is also made. Also in the scenario FTP (File Transfer Protocol) are applied over TCP (Transmission Control Protocol) for transmission of packets.

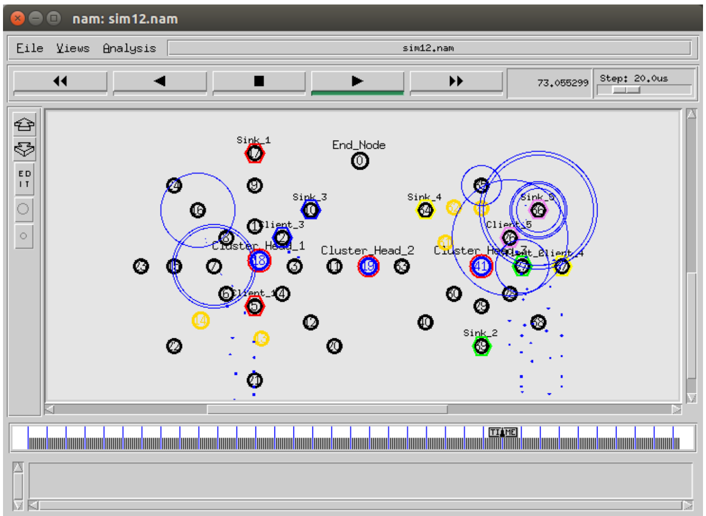

Figure . Implemented scenario

5.2. Simulation Results

The comparison between IEEE 802.11, S-MAC and Modified S-MAC is carried out with the help of AWK file which is an Interpreted Programming Language. AWK files are used to calculate throughput, packet delivery ratio, packet loss count and energy, further their result are listed in tabular form in Table 2 and Table 3, where AEC is defined as Average Energy Consumption and PDR resembles to Packet Delivery Ratio.

Table . Comparison of Parameters

	Throughput (kbps)		PDR	
	AODV	*DSDV*	*AODV*	*DSDV*
IEEE 802.11	602.48	912.09	0.2008	0.3040
S-MAC	32.51	1013.92	0.0123	0.3380
Modified S-MAC	24.75	779.89	0.0095	0.3247

Table . Comparison of Parameters

	Packet Drop Count		AEC (joule)	
	AODV	*DSDV*	*AODV*	*DSDV*
IEEE 802.11	3263	2196	16.2381	16.9048
S-MAC	204	2988	7.6190	14.3095
Modified S-MAC	546	1980	5.7142	6.7857

It is clear from the above results given by AWK files that whether AODV (Ad-hoc On-demand Distance Vector) or DSDV (Destination Sequence Distance Vector) routing is considered, Modified S-MAC gives over-all better results. It may happen that when packet loss count is considered AODV reacted more properly giving lesser packet drops. But sill comparing all the parameters, Modified S-MAC gives satisfactory outputs under DSDV.

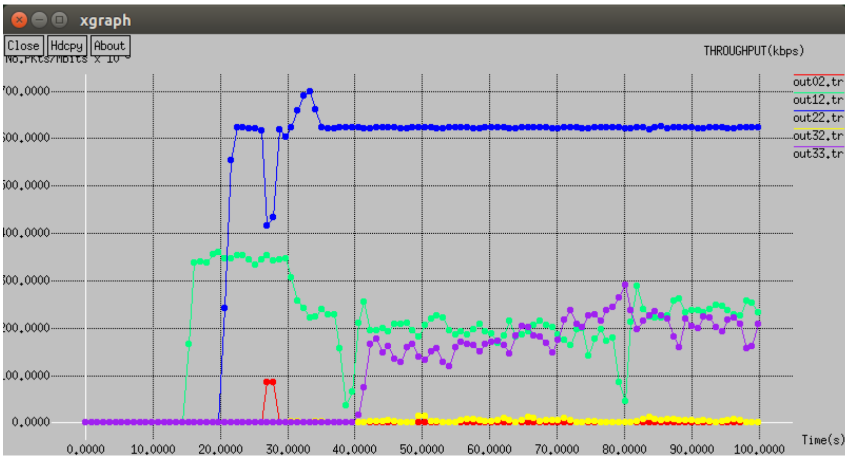

Figure . Xgraph Modified S-MAC Throughput

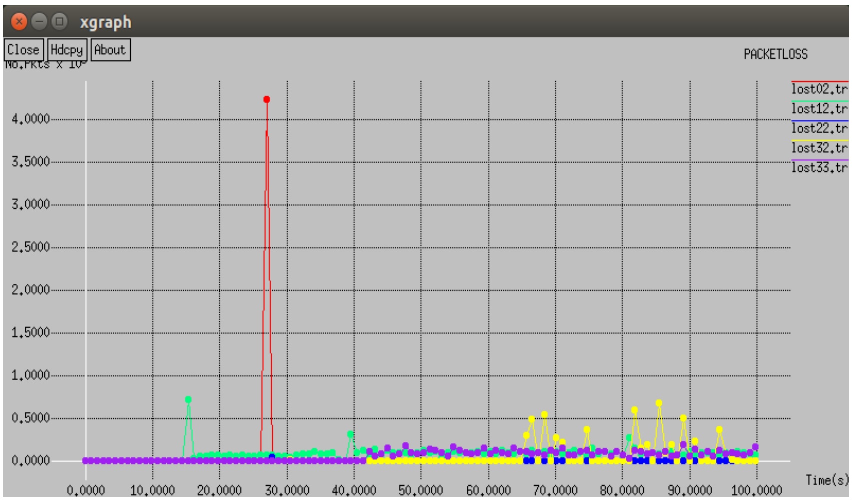

Figure . Xgraph Modified S-MAC Packet Loss

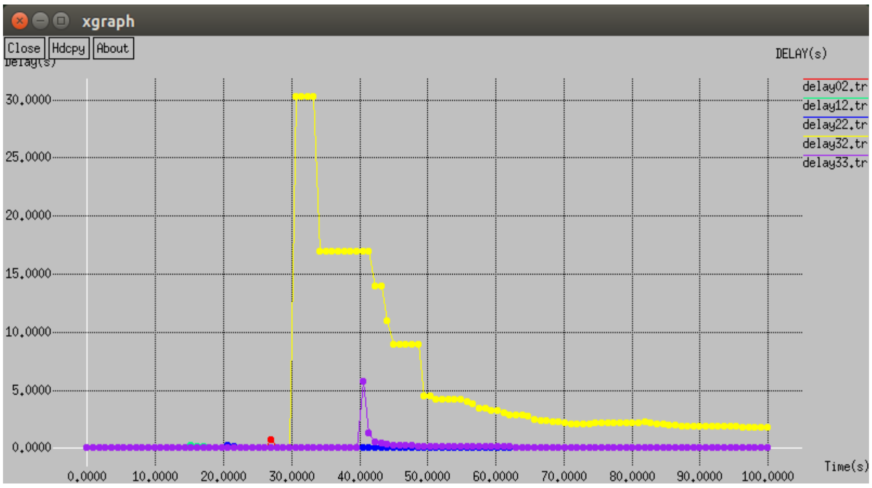

Figure . Xgraph Modified S-MAC Delay

Figure 7, Figure 8 and Figure 9 shows Xgraph for throughput, packet loss count and delay. The scenarios is such where five pairs of client and sink are communicating with each other and values for throughput, packet loss count and delay for each such pair is plotted with a different color. So that it becomes easy to compare parameters in-between various pairs.

The Xgraph plotted easily shows that with a vivid throughput considerable lesser packet drop count and lesser delay can be achieved. Besides this the results obtained from AWK files supports this. Two more additional parameter of Packet Delivery Ratio and Average Energy Consumption are obtained with the help of AWK files to enhance the results, where also Modified S-MAC works promisingly.

VI. CONCLUSION AND FUTURE SCOPE

6.1. Conclusion

It can be concluded from research conducted and simulation that SMAC definitely improves result in comparison to traditional IEEE 802.11 and even moving one step further Modified S-MAC improves the results in comparison to S-MAC. Also when we compare the parameters in scenario, one can easily conclude that although IEEE 802.11 gives more throughput in comparison to S-MAC and even Modified S-MAC, but still when other parameters are considered i.e. packet delivery ratio, packet drop count and energy consumption, Modified S-MAC results in promising outputs. Besides this these results prove that out of AODV and DSDV applied across scenario, DSDV is most suitable. Though main motivation is towards MAC layer only, but proper selection of routing algorithm even improves the results to one more level. Also Xgraph supports the results given by AWK files.

6.2. Future Scope

Various techniques improving the fixed duty cycle of S-MAC can be evolved, because S-MAC is most basic and simplest in its terms for MAC layer of WSN. Also similar to this research, various already proposed techniques can be merged with each other in order to some more fruitful outputs. The drawback of this technique is in terms of packet drop count. Though other parameters were improved up-to certain extents, but packet delivery ratio was not improved up-to the expected extends. Thus one can even go for modification of this technique to improve the results even further.

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