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Priority Scheduling Algorithm for Traffic in a LTE-based Defence Mesh Network Incorporating Centralised Scheduling Architecture

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ABSTRACT

Wireless mesh networks (WMN) are the networks of future and can operate on multiple protocols ranging from WiFi, WiMax to long term evolution (LTE). As a recent trend defence networks are incorporating off-the-shelf, state of the art commercial protocols to enhance the capability of their networks. LTE is one such commercially available protocol which is easy to deploy and provide high data rate which can be ideally implemented in WMN for defence networks. To enable these high data rate services LTE-based defence mesh networks (DMN) are the requirement of the day and future. However, LTE-based DMN are prone to congestion at times of active operations or full-fledged war. The congestion scenarios may lead to LTE packet loss. Hence, it is pertinent that these networks amalgamate information grooming algorithms to alleviate the throughput of the network in peak hour conditions. An efficient priority scheduling algorithm based on class of service prioritisation, data rate consumption and location of origin of traffic in the DMN is proposed. The simulations demonstrate that by incorporating the proposed priority scheduling algorithm, the overall packet loss of priority packets in the DMN reduces substantially.

Keywords: WiMax; OFDM; Long term evolution; Data rate; Class of service; Quality of service; Wireless mesh networks

1. INTRODUCTION

Defence networks are ever evolving and incorporating state of the art technologies to improve performance of the network in terms of throughput, and also ensuring quality of service (QoS). Long term evolution (LTE) is a well established protocol in the telecommunication world today and hence LTE-based defence mesh networks (DMN) will be the future of Defence Networks. LTE provides high data rate (DR) services to the end user and fulfils the expectations of defence users of today. However, with high DR services being handled by LTE-based DMN these networks will be prone to congestion and require a mechanism to prevent large packet losses.

It is evident that LTE-based DMN will provide robust reliable and fail-safe communication for communications in the tactical battle area. Further, it is important to understand and appreciate that any telecommunication network will be designed and implemented with only 40 to 50 percent of peak traffic load statistically. This makes the network practical and economical to implement. However, in the event of active operations or a situation of full-fledged war, the defence users of LTE-based DMN will start to transmit voice, data and video traffic continuously to inform their respective headquarters of the impending situation. This will lead to total blocking of the network or partial failure of certain subnets of the LTE-based DMN. Hence, in such situations, it is necessary to classify traffic and priorities traffic according to type of service (voice, video and data), area of origin in the network, amount of network resource utilisation the service desires and delay tolerable by the service. The above prioritisation will result that important traffic reaches the higher headquarters to facilitate real-time decision making in times of active operations or full-fledged war and further dropping of low priority traffic to decongest subnets of the LTE-based DMN.

Hence, a priority scheduling algorithm (PSA) is proposed in this paper which assigns weights to each connection request for every wireless node in the LTE-based DMN. Every connection request is classified into three different classes thus ensuring differentiated service. The number of hops and data rate requested by each service request is adequately utilised with the class of service to calculate weight for each connection request. The weights thus assigned to each connection request on the basis of above connection parameters are arranged in a fashion that the lighter requests are given higher priority and are assigned a better quality of wireless link for transmission. The incorporation of the proposed priority scheduling algorithm (PSA) will ensure lower packet loss in the network and substantially improve the QoS in the LTE-based DMN as discussed in the study.

2. RELATED WORKS

An overview of related work for traffic scheduling in LTE-based WMN is presented here. Traffic grooming algorithms in WMN have been adequately researched and a survey of traffic scheduling in WMN is available[2]. Various algorithms for traffic

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scheduling in WMN are proposed[3-8]. There has been substantial amount of work in the field of traffic scheduling in LTE-based wireless networks Traffic scheduling for disjoint multipath-based routing networks is discussed[9]. Delay-aware QoS scheme for mixed traffic flow in LTE networks is researched[10]. Further performance evaluation of mixed traffic scheduling algorithm in LTE network[11], and analysis of scheduling policies for VoIP traffic in LTE- Advanced network[12] has been done. Experiments in fair scheduling for 4G networks are available[13]. Hierarchical taylor-made scheduling for data traffic with prioritisation in LTE networks[14] and delay based scheduling algorithm for video traffic in LTE networks[15] has been researched. Delay scheduler with throughput -fairness in LTE wireless networks is available[16]. TCP-aware scheduling in LTE networks is also available[17]. Scheduling with channel quality indicator for real-time traffic in LTE networks has been done[18]. Ensuring QoS in LTE networks by traffic scheduling has been adequately researched[19-21]. Further, priority based traffic scheduling and utility optimisation for smart grids[22] has shown that priority based traffic scheduling is an imminent requirement to optimise available bandwidth. Though initial study of priority based algorithms for traffic grooming in wireless defence networks have recently been undertaken by authors[23-29], however the issue of giving weightage to information originating from important areas and for important class of user in the LTE-based DMN has not been explored previously.

3. PRIORITY SCHEDULING ALGORITHM

LTE-based DMN provide robust, redundant and reliable communication to the defence users. The LTE-based DMN will also facilitate the defence users to transport bandwidth heavy service like video transfers and video conferencing from edge of the battlefield in forward areas to the defence headquarters located in the hinterland through a mesh of high data links in the LTE-based DMN. However, typically these telecommunication networks are planned, designed and implemented for a maximum of 40 per cent to 50 per cent of peak loads. During an event of active operations or full-fledged war, each defence user will start pumping bandwidth heavy traffic into the LTE-based DMN in order to ensure that his higher headquarters gets the real-time information of the impending situation in its area of responsibility. Thus, the entire network or certain subnets of network will get congested and will result in denial of service to the defence users of the LTE-based DMN.

On the other hand, it is pertinent to understand that the higher headquarters in the hinterland may be concentrating on information being originated from certain subnet or circle of LTE-based DMN which is in contact to the enemy. On the other hand, information from other subnets may not be important to the higher headquarters during that phase of the battle. In the light of the above viewpoint, the higher headquarters which requires real-time information to take immediate decisions that may shape the direction of battle in own favour, will like to drop traffic from low priority circles which are unnecessarily congesting the network and give higher priority to traffic originating or destined to affected or active circles in the event of active operations or full-fledged war.

Therefore, LTE-based DMN requires an efficient traffic scheduling algorithm to ensure that high priority packets are dropped less in comparison to low priority packets. Various parameters affecting the performance of PSA and the various steps of the algorithm are described in details, followed by the proposed PSA architecture. The functionality of PSA is presented below.

3.1 CLASS OF SERVICE QUANTISATION OF TRAFFIC

The PSA priorities the information from the users into multiple schemes of service so as to assure QoS. This division of information into multiple schemes of service is essential to ensure that a higher scheme of information from the user is not neglected during clogging of portions of the network during peak hour conditions in the LTE-based DMN. To ensure the above concept, the PSA divides the information from the users into the following schemes of traffic:

(a) Real time information (RTI) (S = 3): for voice and live video applications.
(b) Non-real information (NRI) traffic (S = 2): for compressed video information.
(c) Delay tolerant information (DTI) (S = 1): for movement of files.

This division of information into schemes of service is done by ‘request handler’, located at every wireless node in the LTE-based DMN.

3.2 Prioritisation of Sector

The LTE-based DMN is organised into five sectors and one control headquarters for better command and control. In the scenario of active operations or full-fledged war, the traffic in the LTE-based DMN will increase substantially and the inter-sector traffic will experience high congestion. Further any active operation or a full-fledged war will be concentrated to a particular sector. Hence, the sector in which concentration of active operations or full-fledged war is taking place at the moment will be the Active Sector and the traffic generated from the active sector will be of utmost importance for the national security. Hence, the packets originating from the Active Sector needs to be given the highest priority and should be the last ones to be dropped in case of congested wireless links.

In the simulations, we have assumed that the active operations or a full-fledged war is concentrated in Sector-A. Therefore, Sector-A is designated as the active sector. Sector-B is the adjacent sector and therefore has been given second priority as it is assumed that this sector is going to have an impact on the operations in Sector-A being the active sector. Sector-C has been given the last priority as it has been assumed for the simulation process that the activities in the sector has little or no impact in the operations in Sector-A. In view of the above assumptions, each packet originating from a certain sector will be given a sector priority (SP) value as given below:

(a) Packets from Sector-A (active sector) : SP = 1.
(b) Packets from Sector-B : SP = 2.
(c) Packets from Sector-C : SP = 3.

3.3 Algorithm Framework

The constituents of the framework for a LTE-based DMN are request handler, request prioritiser, bidirectional wireless links and control links[23]. The described framework of the constituents of a LTE-based DMN for application of PSA has been given in Fig. 1.

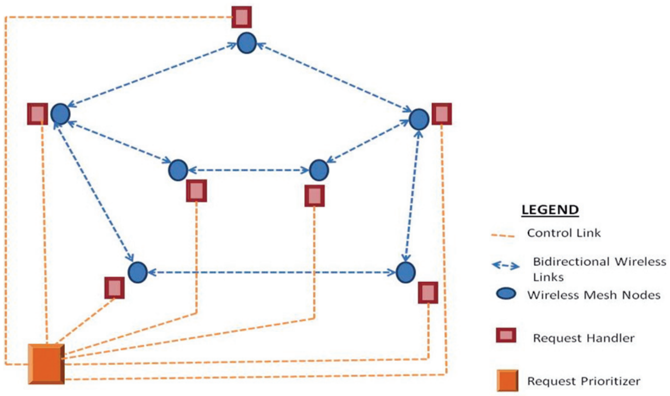

Figure 1. Framework for PSA.

3.4 Algorithm Functionality

PSA aims to enhance the delivery of packets which either carry important information or carry information which has been originated from an important sector of the LTE-based DMN. The above can be implemented by ensuring that these important packets are transferred first (in priority) in the LTE-based DMN during an event of clogging of portions of the network during peak hour conditions. PSA incorporates processes of handling of user information[23].

Extraction of parameters from connection requests: PSA needs to extract important parameters from the user connection requests and process in centrally. These important parameters are extracted by the 'request handler' positioned at every wireless node of the LTE-based DMN. Further, every request handler forwards these important parameters to a central request prioritiser for processing the information as per the steps of the PSA algorithm. After processing at the central request priotiser, the weighted results are forwarded to the respective request handlers for processing and transmission of the respective packets in order of their assigned weights. The various important parameters extracted from the user connection requests are enumerated as follows:

(a) Hop count (H): The source eNodeB number and destination eNodeB number is extracted from information bearing packet received by the serving eNodeB of the LTE-based DMN. The above eNodeB numbers are used to calculate the route of the information carrying packet in the LTE-based DMN utilising Djikstra algorithm. The parameter of number of Hops in the LTE-based DMN is extracted from the above.
(b) Tolerable delay (D): The time impediment in ms, an information carrying packet can withstand in the LTE-based DMN, without any deterioration in end user service is extracted from the request handler.
(c) Required data rate (DR): The data speed required by the service requests throughout all links in the LTE-based DMN is provided by the request handler.
(d) Service priority (S): This division of information into multiple schemes of service generated by the user in the LTE-based DMN. The different division of information into multiple schemes will be as given in Section 3.1.
(e) Sector priority (SP): This is the priority of the packet according to its sector of origin and will take values as highlighted in Section 3.2.

The parameters (b), (c), and (d) are extracted from the service request of the user by the request handler and provided to the central request prioritiser on the control link is observed. The parameters (a) and (e) are extracted from the system architecture by the central request prioritiser. The above five metric parameters will be utilised for further processing at the central request prioritiser according to following steps:

Step-1: Generation of a schema for connection demand for every eNodeB in the LTE-based DMN is given in Table 1.

Step-2: After creating the connection demand schema, the Request Prioritiser will derive the weight (W) for each connection demand by using the Eqn. (1) below:-

$$W = H/H_{max} + 1/S + DR / M_d + D + SP \quad (1)$$

The weight derived from Eqn. (1) indicates the portion of communication assets that the connection demand will be requiring for successful delivery of the packets to the destination. The logic of each term in of Eqn. (1) is enumerated as follows:

(a) First term of Eqn. (1) – is a relative of hop count (H) to the highest number of hops (H_{max}), the links span in the LTE-based DMN. H_{max} is assumed to take a value of '4' as per the architecture in Fig. 2.
(b) Second term of Eqn. (1) – is a relative of service priority (S) to the maximum value of S possible, which is incidentally '3' as brought out in Section 3.1.
(c) Third term of Eqn. (1) – is a relative of the data speed

Table 1. Connection demand

Source Id	Destination Id	No of Hops (H)	Data rate required (DR) (in Mbps)	CoS Required (S)	Tolerable Delay (D) (in msec)	Sector priority (SP)
001	003	2	0.2	2	0.45	1
002	005	3	0.3	1	0.30	3
001	004	3	0.4	3	0.50	1
002	006	4	0.5	2	0.40	3
003	006	3	0.6	2	0.35	2
005	002	3	0.7	1	0.25	2

Note: The figures in Schema are random to elaborate PSA steps.

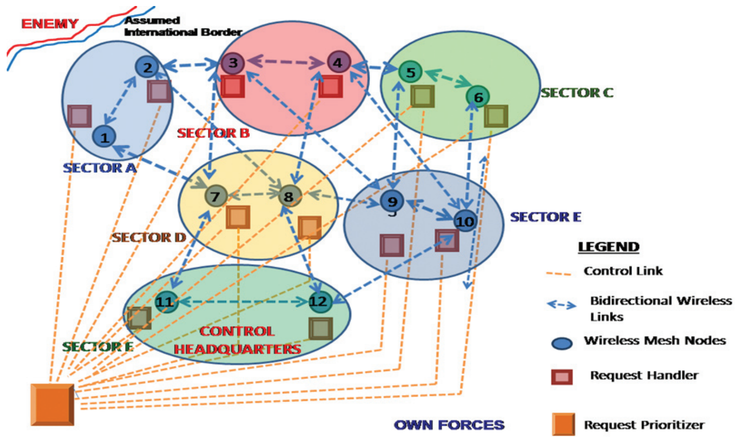

Figure 2. Simulation architecture for PSA in LTE-based DMN.

required (*DR*) by the service requests throughout all links in the LTE-based DMN to the highest value of data speed (M_d), designed in the LTE-based DMN which is incidentally 7 Mbps.

(d) Fourth term of Eqn. (1) – The time impediment in millisecs, an information carrying packet can withstand in the LTE-based DMN, without any deterioration in end user service.

(e) Fifth term of Eqn. (1) – gives the priority of a packet depending on the sector of origin. Packets from Sector-A (active sector) have been given the highest priority, packets from Sector-B (adjacent sector to the active sector) the next priority and packets from Sector-C have been given the least priority. The value of the parameter assigned to each packet is as given in Section 3.2.

At each eNodeB, the derived service demand packets will be stacked in queue in such a way that packets which have been stamped with greater value of weights will be positioned first in order of transmission in every eNodeB of the LTE-based DMN. The weight (W) figures for all service demands for all rows of the connection demand schema in Table 1 will be derived and a weighted demand schema will be generated as given in Table 2.

Step-3: The rows in the in weighted demand schema at Table 2 is reoriented in such a way that lower value derived Weights (W) are on top and higher value derived W are below. This new reoriented schema is called the prioritised queuing schema and given in Table 3.

Step-4: The Prioritised queuing schema (derived for every eNodeB in a LTE-based DMN), Table 3 from Step 3 will deduce to the sequence of transmission of information carrying packets for every eNodeB of the LTE-based DMN. The above deduction will take place at the central Request Prioritizer and communicated to the respective request handlers of the LTE-based DMN. The arrangement will be repeated for the every row of Table 3 till there are no connection demands remaining in Table 3. Step-4 will ensue for all the eNodeBs in the LTE-based DMN.

3.5 Complexity of Algorithm

The computational complexity of PSA as given in Eqn. (1) of Step 2, as given in sub-section *D* is of the order O(1), which is minimal. The computational complexity of the entire algorithm from Step 1 to Step 4 of sub-section *D* is equal to O(nlog(n)) + O(1) ~ O(nlog(n)). The PSA will be implemented as software in existing hardware of the LTE architecture (eNodeB) and the cost factor for the implementation will not be substantial; however, will optimize the utilisation of

Table 2. Weighted demand schema

Source Id	Destination Id	No of Hops (H)	Data rate required (DR) (in Mbps)	CoS required (S)	Tolerable delay (D) (in ms)	Sector priority (SP)	Weight (W)
001	003	2	0.2	2	0.45	1	2.47
002	005	3	0.3	1	0.30	3	5.09
001	004	3	0.4	3	0.50	1	2.62
002	006	4	0.5	2	0.40	3	4.97
003	006	3	0.6	2	0.35	2	3.68
005	002	3	0.7	1	0.25	2	4.10

Note: H_{max} has been chosen to be 4 hops as per algorithm architecture of Fig. 2 and M_d is kept at 7 megabits per second (Mbps).

Table 3. Prioritised queueing schema

Source Id	Destination Id	No of Hops (H)	Data rate required (DR) (Mbps)	CoS required (S)	Tolerable delay (D) (s)	Sector priority (SP)	Weight (W)
001	003	2	0.2	2	0.45	1	2.47
001	004	3	0.4	3	0.50	1	2.62
003	006	3	0.6	2	0.35	2	3.68
005	002	3	0.7	1	0.25	2	4.10
002	006	4	0.5	2	0.40	3	4.97
002	005	3	0.3	1	0.30	3	5.09

network resources substantially, to ensure more services being provisioned on the existing network. The above will be aptly demonstrated in the simulation and their results in Section 4.

4. SIMULATION SETUP AND RESULTS

The architecture considered for simulation of PSA in LTE-based DMN is given in Fig. 2. The DMN has been divided into 5 sectors, each having 2 nodes each, and a control headquarters with 2 nodes for better command and control. The voice, video and data sensors are connected to these nodes and the information is passed through inter and intra sector links to reach the destination at the control headquarters. The architecture consists of 12 wireless nodes and 20 bidirectional wireless links.

On the control plane, the architecture consists of a request handler collocated at each wireless node. A central request prioritiser handles all control functions for the DMN. The request handlers collocated at each wireless node are connected to the central Request Prioritiser by a control link. The routing controller is responsible for running the proposed PSA and routing of information in the LTE-based DMN of Fig. 2.

The simulation has been done in OMNET++ framework. The simulation has been carried out in OMNET++ (version 4.2.2), which is a discrete event simulating environment. INET framework has been used inside the OMNET++ environment, which facilitates simulation of the algorithm in LTE-based DMN. The conjecture base on which the evaluation of PSA has been done is given as follows:

(a) The requests for channels/connections are random in nature. The stochastic behaviour of the random request follows a poisson distribution. Further, the time of arrival between two events (two connection requests) of connection requests in succession, follow a distribution which is exponential in nature.
(b) The greatest value for data rate of every wireless channel is kept at 7 Mbps. The increments of requests in data rate thereafter are in multiples of 100 Kbps.
(c) The data units/ packets are inducted arbitrarily amidst all originating and destined wireless eNodeBs. A channel demand is spoken to be not availed or denied in case the requisite bandwidth is not allocated in any of the intermediate links.
(d) The consummation of PSA is quantified in quantum of packet loss (PL) wherein; the more diminished the PL, finer the performance of network. Packet increase (PI) is commensurate to accrual in cardinal of service users in the LTE-based DMN.
(e) The quantum of data units developed by every eNodeB in the LTE-based DMN is gradually augmented for the evaluation and analysis of PSA to a value of 11000 data units. The above process will aftermath in greater quantum of PI in the LTE-based DMN.

The evaluation and analysis of PSA is conducted in three phases.

4.1. Phase 1

In the first phase of the simulation, the functionality and performance of PSA algorithm was evaluated in the simulation architecture of Fig. 2. The traffic in terms of voice, video and data packets have been generated from all wireless sensor nodes connected to each wireless node of LTE-based DMN. The simulation result of number of dropped packets with increasing number of input packets in the simulation architecture of Fig. 2 is as shown in Fig. 3.

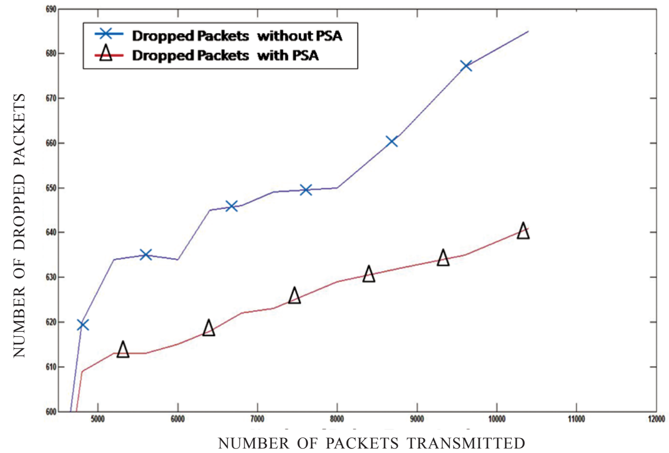

Figure 3. Performance of PSA.

From the graph of Fig. 3, we can understand that the number of dropped packets have reduced substantially (around 50 packets for 10000 packets input in the network) on incorporating the PSA in the simulation architecture of Fig. 2. Hence, we can infer that there is good amount of enhancement in the overall throughput of the network by associating PSA in the LTE-based DMN. The improvement increases drastically as the more number of packets are entering the network.

4.2. Phase 2

In the next phase of simulation, the dropped packets of each sector has been analysed and the simulation result is given in Fig. 4.

From the graph of Fig. 4, the following inference is deduced:

(a) Number of dropped packets of Sector A are minimum,

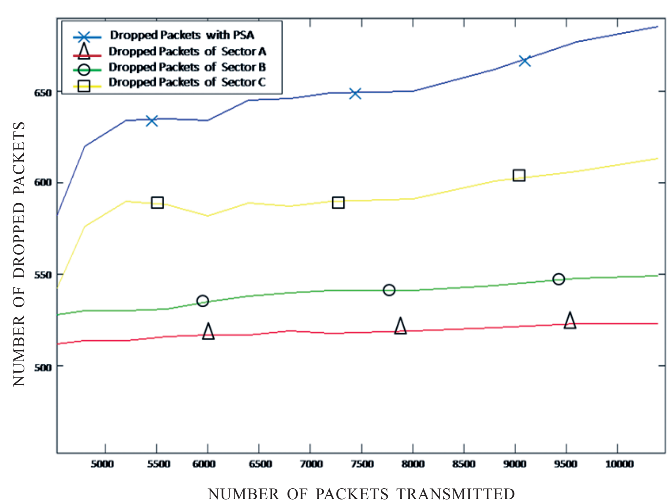

Figure 4. Sector wise packet loss analysis.

Sector B has relatively more dropped packets and Sector C has maximum dropped packets.

(b) The above is due to the fact that the PSA in the simulation architecture of Fig. 2 has assigned packets from Sector A with the highest priority, packets from Sector B with lower priority and packets from Sector C have been assigned the lowest priority.

Therefore, we infer that by the incorporation of PSA in the LTE-based DMN has resulted that minimum number of packets are dropped from high priority sector which is the 'active sector' for the Control Headquarters. This results that during active operations or full-fledged war the most important packets from the active sector (which is at the helm of operations) are rarely dropped and given the highest priority to reach the control headquarters. This will facilitate fast and effective decision making in the interest of national security.

4.3. Phase 3

In the third phase of simulation, the class-wise packet analysis for LTE-based DMN architecture of Fig. 2 has been done and the results are given in Fig. 5.

From Fig. 5, we can infer that the packets of Class A have the highest priority, followed by packets of Class B and the packets of Class C have the minimum priority for the entire network. Hence, Class A packets attain the highest throughput in the entire network in comparison to other classes of traffic. The above is in accordance with the prioritisation of packets done by PSA in the simulation architecture of Fig. 2.

The PSA primarily incorporates two levels of prioritisation i.e. CoS prioritisation and sector-wise prioritisation in the simulation architecture of LTE-based DMN of Fig. 2. We have seen in all the above simulation results that the number of dropped packets during the time of congestion in the network (at times of active operations or full-fledged war) has drastically reduced for packets of high priority class and packets originating from high priority sector which is the active sector. The reduction of packet loss (thereby reducing the need to retransmit) in critical time (during active operations) is highly desirable in DMN.

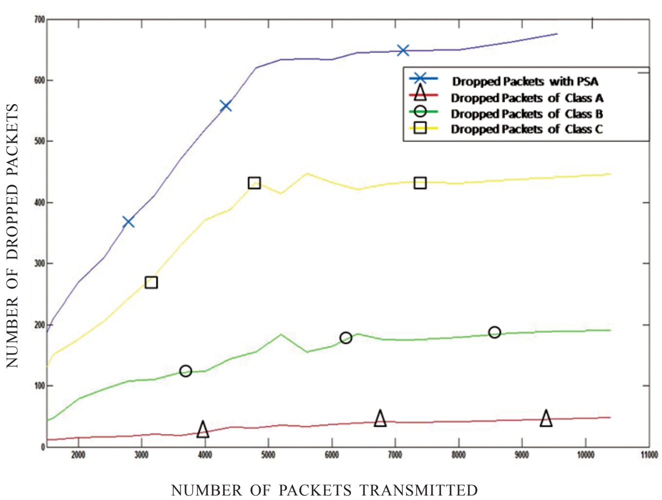

Figure 5. Class-wise packet loss analysis of all three sectors in LTE-based DMN.

5. CONCLUSIONS

LTE-based DMN is the solution for current and future defence networks. Due to high traffic inflow in the LTE-based DMN at times of active operations or full-fledged war, the LTE-based DMN will experience high congestion in the wireless links resulting in high packet loss of critical information from the active sector. The proposed PSA will improve the packet loss in the network and incorporate QoS in the network, which will improve the throughput of packets from high priority sector and for high priority class. The same has been validated in the simulation results and analysed.

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