QoS Deployment Strategies Evaluation in PTN based Power Communication Networks

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***Abstract*—Various services are transmitted in the power communication networks, which require differentiated QoS guarantee. Packet transport network (PTN) technology can meet the requirements. In this paper, QoS mechanisms of PTN are investigated and different QoS deployment strategies are proposed. To verify performance, DiffServ module of network simulator (NS-2) is employed. Simulations check the influence of RED parameter setting, scheduling mode and dropping mode. Results show that (1) Influence of RED parameter setting is not significant; (2) Scheduling mode affects the performance greatly, and round robin and priority scheduling are recommended; (3) Dropping mode influences the packet loss rates of different traffic classes but does not change the overall performance.**

***Index Terms*—QoS, PTN, Power communication networks, Performance evaluation**

I. Introduction

Power Communication Networks (PCN) serves for manufacture, management and sell of power grid. With the development of Intelligent Power Grid, more and more services come forth. To meet the transmission requirements of diverse services in different systems of PCN (including manufacture and dispatching control system, management information system, and power sell system), differentiated QoS guarantees are needed.

Packet transport network (PTN), which is a packet based and connection-oriented multi-service transmission technology, conforms to the trend of PCN (broadband, IP-based forwarding, intelligence and service diversity). Since 2008, ITU-T and IETF set up a Joint Work Term (JWT) [1] to deal with the standardization task of MPLS-TP [2-3] based PTN, which involves five aspects: data plane, OAM, network security, network management and control plane. In the future, PTN will become an important technology in core layer and convergence layer of PCN and other industry networks.

There are many kinds of services in PCN, including dispatching telephone, video and device surveillance of substation, thunder monitoring, video conference, etc. Different services have their own requirements on delay, jitter and bandwidth. PTN-based PCN must provide QoS mechanisms [4-6] to meet differentiated requirements. As we know, QoS mechanisms include stream classification, labeling, rate limitation, bandwidth guarantee, traffic shaping, and scheduling. In PTN, Differentiated Service (DiffServ) is utilized to implement QoS, with the goal of creating a service-oriented QoS guarantee [7-10].

In the previous work [11], we design a PTN based PCN architecture for power grid of Jiangxi province in China and discuss QoS deployment issue to support various services. However, performance evaluation is not provided. In this paper, we perform comprehensive simulations and analyze the results.

The rest of the paper is organized as follows. Introduction of MPLS-TP based PTN and QoS mechanisms of PTN are introduced in Section II and Section III. Topology and services of Jiangxi province's PCN are presented in Section IV and Section V. Section VI discusses the simulation environment and settings. Performance evaluation and discussion are presented in Section VII. Finally, Section VIII concludes the paper and points out future work.

II. MPLS-TP based PTN

MPLS-TP, which is the enhancement of MPLS, is the basis of PTN. MPLS technology is suitable for many application scenarios because it has powerful traffic engineering capabilities. However, the service providers are not willing to launch wide scale deployment in metro and aggregation networks because these costs are very high. On the other hand, maintenance engineers and technicians are familiar with SONET/SDH operations and maintenance procedures. If launching MPLS deployment, they have to learn more about MPLS technology, including its principle, design and administration. Furthermore, operations, administration, and maintenance (OAM) functions are absent in MPLS. Therefore, monitoring and fault management functions of MPLS are poor.

MPLS-TP, which is proposed by IETF, is a transport profile of MPLS. It is a network layer technology used in transport networks and it offers an MPLS implementation. In MPLS-TP, many features are removed because they are irrelevant to those connection-oriented applications. Furthermore, some mechanisms are added to support transport functionality.

MPLS-TP reduces the equipment, operation and maintenance costs by simplify application scenarios of MPLS. Data plan is apart from control plane in MPLS-TP, resulting in high reliability and flexibility.

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Figure 1 shows the feature comparisons between MPLS and MPLS-TP.

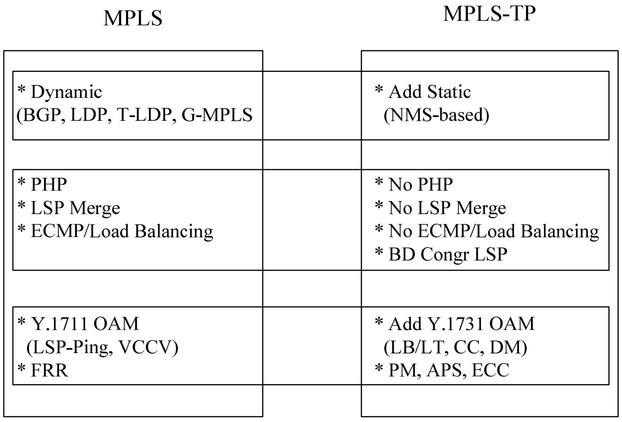

Figure 1. Comparison between MPLS and MPLS-TP

At forwarding plane, several functions are adjusted to facilitate network management capability and to improve network transmission capability. First, LSP merge is prohibited to enhance end-to-end OAM capability. Second, penultimate hop popping is also prohibited. Instead, the outer MPLS label is used as the OAM identifier. Third, load balancing and equal cost multiple path mechanisms are prohibited because they could lead to troubleshooting problems. Finally, to allow MPLS-TP based networks to transmit and receive along the same path, bidirectional congruent LSP is added.

Control plane is optional in MPLS-TP.

In addition, OAM and survivability functions are supported to reduce network operational complexity when performing network performance monitoring and management, protection switching, and fault management. When these functions are provided, MPLS-TP could work without any IP layer functions. MPLS-TP OAM tries to provide network monitoring and management tools with the same attributes offered by the traditional transport technologies. For example, the OAM messages are forwarded on the same path as data. That is to say, MPLS-TP OAM is used to monitor PWs or LSPs. MPLS-TP OAM enhances the capabilities of MPLS OAM which is defined in ITU Y.1711, including basic fault monitoring and troubleshooting features at the LSP level, such as virtual circuit connectivity verification (VCCV) and LSP Ping.

"MPLS-TP OAM operates in the context of Maintenance Entities (MEs) that are a relationship between two points of a point-to-point transport path or a root and a leaf of a point-to-multipoint transport path to which maintenance and monitoring operations apply". "Maintenance Entity Group (MEG)" and "Maintenance End Points (MEPs)" are the names of the above two points. Maybe zero or more intermediate points exist in between the two points. These intermediate points are called Maintenance Entity Group Intermediate Points (MIPs). MEG is another OAM functional component. It is an aggregation of one or more MEs which stand in the same transport path. All these MEs are maintained and monitored as a group.

MEPs are responsible for activating and controlling all of the OAM functionality for the MEG. OAM messages for performance monitoring and fault management could be originated and terminated by an MEP. As described in RFC 5586, these OAM messages are encapsulated into an OAM packet, using the Generic Associated Channel (G-Ach). In this case, the G-Ach message becomes an OAM packet. Also an MEP can terminate all the OAM packets it receives from the MEG to which it belongs. From the MPLS or PW label, the MEG to which an OAM packet belongs could be inferred. In case of MPLS-TP section, the MPLS-TP will port the OAM packet that has been received with the Generic Alert Label (GAL) at the top of the label stack.

G-Ach and GAL are two important components of OAM mechanisms in MPLS-TP. With them, operators are allowed to send any type of control traffic into a PW or an LSP. Assigned the label with value 14, the GAL is employed to represent an OAM message, such as LSP Ping.

III. QoS Mechanisms of PTN

QoS mechanisms supported in PTN include (1) traffic classification and marking; (2) traffic policing and shaping; (3) congestion management; (4) queuing and scheduling [12-14].

A. Traffic Classification

Let F be the set of various traffic flow: F=$\{f_1, f_2, \dots f_n\}$. C is the set of traffic class, C=$\{c_1, c_2, \dots c_m\}$ .Traffic flows which have the same QoS requirements will be classified into the same traffic class C_j, i.e. $C_j=g(f_i)$.

Next, traffic label could be mapped into PHB: $y_j=\Phi(x_i)$, where x_i refers to the value of DSCP field and y_j represents the value of PHB. Notice that PHB = {CS7 , CS6, EF, AF4,AF3,AF2,AF1, BE} in PTN.

B. Traffic Policing and Shaping

Traffic policing monitors network traffic and makes a determination of whether the traffic accords with the predefined contract. Consequently, traffic shaping takes steps to control the traffic rate so that the contract could be ensured. Leaky bucket and token bucket are two methods that are often used when performing traffic shaping. Procedures of a two rate three color marker [10], which is commonly used, is shown in Figure 2.

There are two token buckets in the figure: P and C. PBS and CBS are the maximum sizes of these two token buckets. Token count TCp/TCc is restricted up to PBS/CBS within one PIR/CIR times per second. At time 0, P and C are set to full, i.e., TCp(0) = PBS and TCc(0) = CBS. At time t when a packet with B bytes arrives, the following two rate three color marker works.

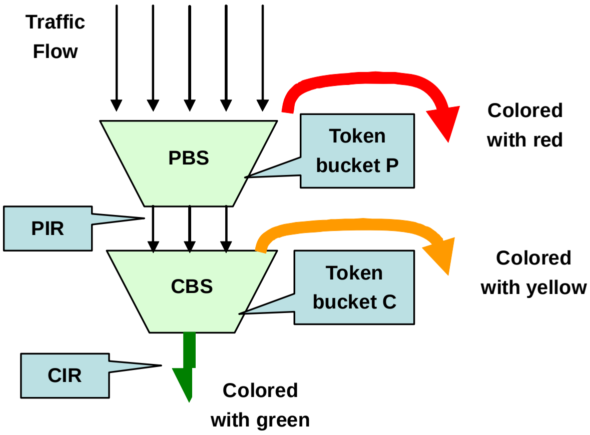

Figure 2. Procedures of two rate three color marker

If in Color-Blind mode,

```
if (TCp(t}-B<0)
  PK = red:
else if (TCc(t}-B<0) {
  PK = yellow;
  TCp -= B;
}
else {
  PK = green;
  TCp -= B or TCc -= B;
}
```

If in Color-Aware mode,

```
if (PK = red or TCp(t)-B<0)
  PK = red;
else if (PK = yellow or TCc(t)-B<0) {
  PK = yellow;
  TCp -= B;
}
else {
  PK = green;
  TCp -= B or TCc -= B;
}
```

C. *Congestion Management, Queuing and Scheduling*

Congestion management is responsible for preventing traffic flow from congestion. The way to finish this task is to drop packet properly. Two congestion control mechanisms, called Tail Drop (TD) and Weighted RED (WRED), are required to be provided in PTN.

By employing queuing and scheduling, the packets which should be dropped could be selected when congestion occurs, according to service PHBs. Ordinarily, high priority service has the smallest dropping probability. There are several queuing approaches: First-in first-out queuing (FIFO), Priority queuing (PQ), Fair queuing (FQ) and Weighted Fair queuing (WFQ).

D. *Hierarchical QoS*

As for produced PTN devices, when a PTN device acts as DiffServ edge node, it is capable to implement Hierarchical QoS (HQoS) in the node. Figure 3 gives a simplified description on where HQoS mechanisms

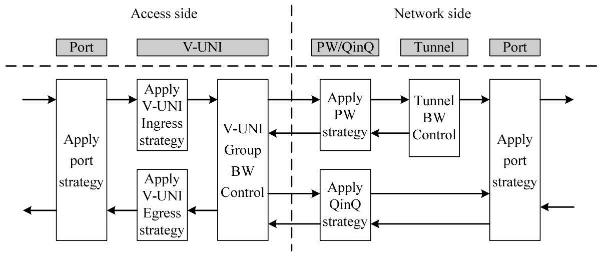

Figure 3. Simplified HQoS framework in PTN

locate and how they are applied. In a PTN device, there are four QoS levels: *V-UNI*, *PW/QinQ*, *Tunnel* and *Port*.

(1) *V-UNI* level is designed to distinguish different services. At this level, V-UNI Ingress strategy and V-UNI Egress strategy can be created and applied for source and destination services respectively. V-UNI Ingress strategy helps to establish the mapping between service and its corresponding CoS (PHB) and queuing strategy. CoS parameters (include CIR, PIR, etc.) are also determined here. Moreover, at this level V-UNI Group can be created to perform bandwidth control on certain combination of multiple V-UNI.

(2) *PW/QinQ* level locates at network side. A PW/QinQ strategy always matches a V-UNI (if V-UNI group is not created) or a V-UNI group. Bandwidth control can be performed on a PW/QinQ.

(3) *Tunnel* level. A tunnel always accommodates multiple PWs which have the same destination. On each tunnel we can set a differentiated bandwidth limitation.

(4) At *Port* level, services, which are originated from different ingress ports but mapped to the same CoS, are aggregated to share a set of CoS parameters as a whole.

IV. PCN TOPOLOGY OF JIANGXI PROVINCE

Figure 4 shows the PCN topology of Jiangxi Province, which combines PTN with OTN. At core layer, there are two OTN core loops which are called southwest and northeast core loops. Under the OTN core layer, there is PTN aggregation layer. Each aggregation loop is connected to a core loop through two PTN devices. Similarly, PTN access loop is connected to PTN aggregation loop. Finally, access nodes (including substation, dispatching center and power plant) are connected to the PTN access devices.

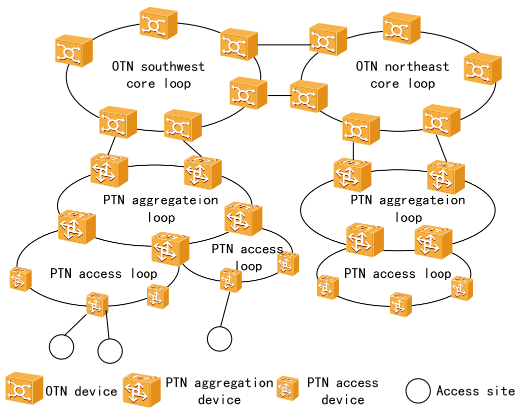

Figure 4. PCN topology of Jiangxi province

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V. SERVICE ANALYSIS OF PCN

Table I shows different services in PCN, which can be classified into four systems: (1) manufacture and dispatching control system; (2) management information system; (3) power sell system; and (4) a system which consists of other services. In this table, RT means real time. The column channel means the channel over which the service is transmitted: ① special line; ② dispatching data network; ③ data transmission network.

TABLE I.

SERVICE LIST IN PCN

Service system	Service name	RT?	channel
(1)	Dispatching telephone	Yes	①
	SCADA/EMS	Yes	①
	Dispatching automation	Yes	①
	Running protection management	No	②
	Running safety management	No	②
	Power measuring	No	②
	Power marketing	No	②
	Dispatcher training (DTS)	No	②
	Dispatching management	No	②
	Thunder monitoring	No	③
	Substation video surveillance	No	③
(2)	Financial management system	No	③
	Material management	No	③
	Engineering management	No	③
	Human resource management	No	③
	Safe manufacture management	No	③
	Office automation	No	③
	Administrative telephone	Yes	③
(3)	Sell decision making	No	③
	Sell service management	No	③
	Sell user management	No	③
(4)	Fiber monitoring	No	③
	Transmission running	No	①
	Transmission management	No	③
	Substation device surveillance	No	③
	Cable monitoring	No	③
	Video conference	Yes	①

There are four node types in PCN of Jiangxi province: (1) substations which locate in access, aggregation and core loops; (2) power plants which often locate in aggregation and core loops; (3) dispatching centers (together with electric power companies), including province-level, city-level and county-level centers. County-level center always locates in access loop. City-level center often locates in the crossover of access and aggregation loops. And the unique province-level center locates in the core loop. (4) Administrative offices, managed by province-level electric power company. The following tables describe services which are transmitted between different node pairs.

TABLE II.

SERVICES TRANSMITTED BETWEEN CITY-LEVEL CENTER AND PROVINCE-LEVEL CENTER

Service name	Direction	Traffic
Dispatching telephone	bidirection	2M
Administrative telephone	bidirection	2M
SG-ERP	bidirection	100M
Video conference	bidirection	8M
Transmission running	bidirection	10M
Transmission management	bidirection	10M
Dispatching data network services	bidirection	155M

TABLE III.

SERVICES TRANSMITTED BETWEEN SUBSTATION AND DISPATCHING

Service name	Direction	Traffic
Dispatching telephone (S1)	bidirection	2M
Dispatching automation (S2)	bidirection	2M
Running protection management (D1)	substation -> center	2M
Running safety management (D2)	substation -> center	2M
Power measuring (D3)	substation -> center	2M
Administrative telephone (T1)	bidirection	2M
Substation video surveillance (T2)	substation -> center	20M
Substation device surveillance (T3)	substation -> center	5M
Thunder monitoring (T4)	substation -> center	2M
Cable monitoring (T5)	substation -> center	3M
Fiber monitoring (T6)	substation -> center	2M

TABLE IV.

SERVICES TRANSMITTED BETWEEN POWER PLANT AND DISPATCHING CENTER

Service name	Direction	Traffic
Dispatching telephone	substation <-> center	2M
Dispatching automation	substation <-> center	2M

TABLE V.

SERVICES TRANSMITTED BETWEEN PROVINCE-LEVEL COMPANY AND ITS ADMINISTRATIVE OFFICE

Service name	Direction	Traffic
Dispatching telephone	bidirection	2M
Video conference	bidirection	8M
Office automation	bidirection	33M

In this paper, we take the services between substation and dispatching center as an example to perform simulations. Table VI shows details of QoS deployment of a substation (bandwidth unit is Mbps) in our previous work, which aims to real PTN devices. Column PW means bandwidth limitation of the PW (an ingress port). Since all the services are sent to the county-level dispatching center, tunnel-level QoS deployment is not required. As for port-level QoS deployment, we can aggregate services that originated from different ingress ports but mapped to the same CoS and let them share a set of CoS parameters. Since port-level deployment is distinct from deployments of other levels, it is not presented.

TABLE VI.

QOS DEPLOYMENT OF SUBSTATION

Port	Service	CoS	CIR	PIR	WRED begin	WRED end	Queue	WFQ weight	PW
1	S1	EF	2	2	100%	100%	PQ	/	2
2	S2	AF4	2	2	90%	100%	WFQ	100	4
3	D1	AF3	1	2	70%	90%	WFQ	90	10
	D2	AF3	1	2	70%	90%	WFQ	90	
	D3	AF3	1	2	70%	90%	WFQ	90	

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4	T1	EF	2	2	80%	100%	PQ	/	50
	T2	AF2	10	20	70%	80%	WFQ	70	
	T3	AF2	2.5	5	70%	80%	WFQ	70	
	T4	AF2	1	2	70%	80%	WFQ	70	
	T5	AF2	1.5	3	70%	80%	WFQ	70	
	T6	AF2	1	2	70%	80%	WFQ	70	

VI. Simulation Environment and Settings

NS-2 [15] is a discrete event simulator designed for networking research. It provides support for simulation of TCP, routing, and multicast protocols over wired and wireless networks.

A. *DiffServ in NS-2*

When employing DiffServ in NS-2, traffic is classified into different categories at first. Secondly, each packet is marked with a corresponding code point to indicate its category. Finally, packet is scheduled accordingly. There are four traffic classes supported in NS-2 DiffServ module (refer to four physical queues), each of which has three dropping precedences (refer to three virtual queues). Consequently, there are twelve treatments of traffic. Each packet is enqueued into a physical RED queue and assigned a dropping precedence.

Each virtual queue is assigned a code point and regarded as a RED queue, which has three parameters: (1) the lower queue length threshold; (2) the higher queue length threshold; (3) the dropping probability. Different priorities could be achieved by setting distinct parameters for different virtual queues. As a result, the packet in the virtual queue with higher priority will receive better treatment when congestion occurs.

There are three major components in NS-2 DiffServ module. The first one is ***Policy,*** defining the service level that a traffic class should receive. Several policy models are defined, and each model could be bound with different parameters. The second one is ***Edge router***, answering for code point marking on packets according to the specified policy. The last one is ***Core router***, answering for examining packets' code points and forwarding them according to predefined virtual queue parameters. In addition, there is a PHB table. Both edge router and core router use this table to perform mapping between code points and physical/virtual queues.

There are six policy models defined in NS-2 DiffServ module:

- Time Sliding Window with 2 Color Marking (abbreviated as TSW2CMPolicer), having only one parameter: committed information rate (CIR). Thus there are two dropping priorities. If CIR is exceeded, the lower dropping priority will be used probabilistically. Otherwise, the higher priority will be adopted.
- Time Sliding Window with 3 Color Marking (abbreviated as TSW2CMPolicer), having two parameters: CIR and PIR (peak information rate). Thus there are three dropping priorities. If PIR is exceeded, the lowest dropping priority will be used probabilistically. If only the CIR is exceeded, the medium dropping priority will be used. Otherwise, the highest priority will be adopted.
- Token Bucket (tokenBucketPolicer), having two parameters: CIR and CBS (committed burst size). There are two dropping priorities in this policy model. If the size of arriving packet is larger than CBS, the lower priority will be adopted.
- Single Rate Three Color Marker (srTCMPolicer), using CIR, CBS, and EBS (Excess Burst Size) as parameters. Also there are three dropping priorities. If EBS is exceeded, the lowest dropping priority will be used. If only the CBS is exceeded, the medium dropping priority will be used. Otherwise, the highest priority will be adopted.
- Two Rate Three Color Marker (trTCMPolicer), using CIR, CBS, PIR, and PBS (peak burst size) as parameters. There are three dropping priorities in this policy model.
- NullPolicer: does not perform packet downgrade.

As for scheduling mode among different physical queues, NS-2 DiffServ module supports Round Robin (RR), Weighted Round Robin (WRR), Weighted Interleaved Round Robin (WIRR), and Priority (PRI). And RR is the default scheduling mode.

Furthermore, NS-2 DiffServ module supports four dropping modes: (1) RIO-C (RIO Coupled), the default dropping mode. The dropping probability of an out-of-profile packet is calculated according to the weighted average lengths of all virtual queues. On the other hand, if an arriving packet is within the profile, the dropping probability will be determined by the size of its virtual queue only. (2) RIO-D (RIO De-coupled), both dropping probabilities are calculated according to the size of one virtual queue. (3) WRED (Weighted RED), all probabilities are calculated according to a single queue length. (4) DROP, similar to the drop tail queue.

In our simulations, different scheduling modes and dropping modes are employed to find the optimal QoS deployment strategy for various services in PTN based PCN.

B. *Topology*

Simulation topology is presented as Figure 5. To generate all traffic classes, four source-destination pairs are employed. Edge router ($E1$ and $E2$) and core router(C) forward packets for the sources. Bandwidth of each link is set as the figure shows.

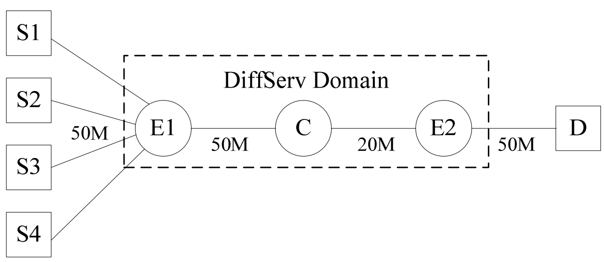

Figure 5. Simulation topology

C. *Simulation Settings*

Since there is difference between simulation and real environments, QoS deployment in Table VI must be

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modified. Dispatching telephone, dispatching automation and administrative telephone are aggregated as the first traffic class (packets of these services will be enqueued into physical queue 0) because these real-time services are sensitive to transmission delay. Aggregated CIR and PIR are both 6Mbps. Since actual traffic is much less than CIR, we generate a 2Mbps flow to simulate this traffic class.

Running protection management, running safety management and power measuring are aggregated as the second traffic class because they all are transmitted in dispatching data network. Aggregated CIR and PIR are set to 3Mbps and 6Mbps. To generate traffic of this aggregated class, we use a random number with Uniform distribution. The minimum and the maximum values of the random number are set to CIR and PIR respectively.

Substation device surveillance, thunder monitoring, cable monitoring and fiber monitoring are aggregated as the third traffic class because they all are transmitted in data transmission network. This traffic class is less important than the former two traffic classes. Aggregated CIR and PIR are set to 6Mbps and 12Mbps. Also a random number with Uniform distribution, whose minimum and maximum values are set to CIR and PIR respectively, is used.

Finally, substation video surveillance itself is regarded as the fourth traffic class because it produces much more packets than other services and can bear packet loss. Traffic of this service, which depends on the contents of the surveillance area, changes tempestuously. To simulate such a service, we employ a random number with Pareto distribution. The average value of this random number is set to 10Mbps which is equals to the CIR. *Shape* is the other parameter of Pareto distribution. A large *shape* produces significant difference among randomly generated traffic values. According to the preliminary experiment results, we set the value of *shape* to 1.2.

TABLE VII.

QOS DEPLOYMENT OF SUBSTATION (SIMULATION)

Queue No.	Service included	CIR	PIR	Random number	
				distribution	Parameter
0	S1,S2,T1	6	6	Constant	2Mb
1	D1,D2,D3	3	6	Uniform	min=3Mb, max=6Mb
3	T3,T4,T5,T6	6	12	Uniform	min=6Mb, max=12Mb
3	T2	10	20	Pareto	avg=10Mb,shape=1.2

Simulation time is 80 seconds, and packet size is set to 100 bytes. For each physical queue, trTCMPolicer is adopted. Default values of RED parameters are presented in Table VIII. Notice that default parameter settings of different physical queues are the same. Thus the table only gives parameter settings of physical queue 0. Let L_i and H_i be the lower and the higher queue length thresholds of virtual queue *i* respectively. And let D_i be the dropping probability of virtual queue *i*. Parameters are set as Table VIII in all experiments of Section VII except those of Section VII.A. Furthermore, default scheduling mode and dropping mode are RR and RIO-C, respectively.

For each experiment, we perform 10 simulations with different seeds and calculate average result.

TABLE VIII.

DEFAULT VALUES OF RED PARAMETERS

Parameter	Value	Parameter	Value	Parameter	Value
L_0	20	H_0	40	D_0	0.02
L_1	10	H_1	20	D_1	0.10
L_2	5	H_2	10	D_2	0.20

VII. RESULTS AND DISCUSSION

A. Influence of RED Parameter Setting

To verify the influence of RED parameters, we use two groups of parameter settings. One is the default setting of Table VIII, in which all physical queues have the same setting. The comparative setting tries to conform to the setting of Table VI. Although D_i remains the same, L_i varies. Table IX shows the setting, in which PQ_i means physical queue *i*.

TABLE IX.

COMPARATIVE SETTING OF RED PARAMETERS

Parameter	Value	Parameter	Value	Parameter	Value
L_0 of PQ_0	50	L_0 of PQ_1	35	L_0 of PQ_2 and PQ_3	35
L_1 of PQ_0	40	L_1 of PQ_1	25	L_1 of PQ_2 and PQ_3	25
L_2 of PQ_0	30	L_2 of PQ_1	15	L_2 of PQ_2 and PQ_3	15
H_0 of PQ_0	50	H_0 of PQ_1	45	H_0 of PQ_2 and PQ_3	40
H_1 of PQ_0	50	H_1 of PQ_1	35	H_1 of PQ_2 and PQ_3	30
H_2 of PQ_0	50	H_2 of PQ_1	25	H_2 of PQ_2 and PQ_3	20

Table X shows the results. In this table "2-1" refers to virtual queue 1 of physical queue 2. For each virtual queue, we calculate three packet loss rates: link loss rate (dropped for queue full, denoted as R_l), early loss rate (dropped by RED mechanism, denoted as R_e) and summed loss rate (denoted as R_s). If there is no packet or no lost packet in a virtual queue, results of the queue will not be shown in the table. Notice that packets in virtual queue 0, 1 and 2 are marked to green, yellow and red respectively.

TABLE X.

PACKET LOSS RATES OF DIFFERENT RED PARAMETER SETTINGS

		2-0	2-1	3-0	3-1	3-2	total
default	R_l	0.0008	0.1371	0.0730	0.9888	0.9994	0.1348
	R_e	0	0.0540	0.0067	0.0008	0.0004	0.0090
	R_s	0.0008	0.1911	0.0797	0.9896	0.9997	0.1438
comparative	R_l	0.0024	0.1365	0.0768	0.9792	0.9973	0.1352
	R_e	0	0.0501	0.0065	0.0005	0.0007	0.0084
	R_s	0.0024	0.1867	0.0832	0.9797	0.9980	0.1436

Recall Section VI.C, we can find that there are no packets in virtual queue 0-1, 0-2, 1-2 and 2-2. Also we can find that R_s of virtual queue 0-0 is zero because packets in this virtual queue are marked to green and the

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virtual queue has the highest priority. Similarly, R_s of virtual queue 1-0 and 1-1 are zero because these two queues have relatively high priority. Furthermore, from the comparison between default and comparative settings, we can draw the following conclusions on influence of RED parameter setting:

(1) Influence of RED Parameters is not significant.

(2) R_e of default setting is larger than that of comparative setting because L_i and H_i of default setting are lower than those of comparative setting. Accordingly, R_l of default setting is smaller than that of comparative setting.

B. Influence of Scheduling Mode

In this sub-section we discuss scheduling mode setting. RR, WRR, WIRR and PRI are investigated. Considering WRR and WIRR, two parameter settings are employed. One is to set weight of PQ_2 to 5 and leave weights of other *PQs* to 1 (denoted as WRR-2 and WIRR-2). The other is to set weight of PQ_3 to 5 and leave weights of other *PQs* to 1 (denoted as WRR-3 and WIRR-3). Since default RED parameter setting is used, only R_s is provided. Table XI gives the results.

TABLE XI.
SUMMED LOSS RATE OF DIFFERENT SCHEDULING MODES

	1-0	1-1	2-0	2-1	3-0	3-1	3-2	total
RR	0	0	0.0008	0.1911	0.0797	0.9896	0.9997	0.1438
WRR-2	0.0021	0.1731	0	0	0.1712	0.9882	0.9998	0.1435
WIRR-2	0.0175	0.3781	0	0	0.1393	0.9882	0.9992	0.1516
WRR-3	0.0172	0.0348	0.0723	0.2370	0.0013	0.7107	0.9998	0.1440
WIRR-3	0.0173	0.0392	0.0821	0.7650	0.0013	0.7106	0.9998	0.2246
PRI	0	0	0	0	0.2282	0.9884	1.0000	0.1435

From the table we can find that:

(1) Total R_s of RR, WRR-2, WRR-3 and PRI are comparative, and WIRR-2 and WIRR-3 show poor performance.

(2) PRI minimizes R_s of high priority queues (PQ_0, PQ_1 and PQ_2) but degrades the performance of PQ_3. Protection levels of PQ_2 in RR are not as high as those in PRI, leading to a packet loss rate of 0.1919.

(3) Since weight of PQ_2 is much higher than those of other physical queues in WRR-2 and WIRR-2, R_s of PQ_2 decreases to zero. However, R_s of PQ_1 and PQ_3 increase significantly. As we know, R_s increase of PQ_1 can not be acceptable. Similarly, WRR-3 and WIRR-3 promotes the priority of PQ_3 and degrades the performance of PQ_1 and PQ_2. Although WRR and WIRR modes could change the default priority of a certain physical queue, we should not set a high weight to the physical queue with low priority.

As a conclusion, RR and PRI are recommended generally. If firm differentiation among various physical queues is needed, PRI is the best choice. Otherwise, RR should be chosen. If a certain physical queue needs special protection, WRR could be employed and a large weight should be set to this physical queue.

C. Influence of Dropping Mode

Dropping mode affects packet loss rate among different virtual queues. RIO-C, RIO-D, WRED and DROP modes are evaluated. From Table XII we can find that the total R_s of different modes are comparative. And the performance of RIO-C is almost the same as that of WRED. Compared to RIO-C, RIO-D/DROP has smaller R_s of PQ_2 and larger R_s of PQ_3. Furthermore, R_s of 2-0 and 3-0 in RIO-D and DROP are much larger than those in RIO-C. As a conclusion, RIO-D and DROP raise the protection level of PQ_2 but degrade the performance of virtual queue 0 (green packets).

TABLE XII.
SUMMED LOSS RATE OF DIFFERENT DROPPING MODES

	2-0	2-1	3-0	3-1	3-2	total
RIO-C	0.0008	0.1911	0.0797	0.9896	0.9997	0.1438
RIO-D	0.0385	0.1151	0.1949	0.7197	0.8761	0.1434
WRED	0.0008	0.1910	0.0794	0.9906	0.9997	0.1438
DROP	0.0526	0.0899	0.2072	0.6974	0.8771	0.1439

VIII. CONCLUSION

In this paper, QoS mechanisms of PTN are investigated at first, especially for the commonly used “two rate three color marker”. Secondly, QoS deployment strategy in real device of PTN based PCN, which is proposed in our previous work, is introduced. Thirdly, NS-2 DiffServ module, simulation topology and parameter settings are discussed. Finally, simulation results are presented. From comprehensive simulations, we find that (1) RED parameter setting does not influence the performance greatly; (2) Influence of scheduling mode is significant, and round robin and priority scheduling are recommended because they provide better protection for high priority services; (3) Dropping mode can affect the packet loss rates among different traffic classes but does not change the overall performance.

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