Priority Based Transmission Rate Control with Neural Network Controller in WMSNs

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ABSTRACT

Wireless Multimedia Sensor Networks (WMSNs) are networks of wirelessly interconnected sensor nodes equipped with multimedia devices, such as cameras and microphones. Thus a WMSN will have the capability to transmit multimedia data, such as video and audio streams, still images, and scalar data from the environment. Most applications of WMSNs require the delivery of multimedia information with a certain level of Quality of Service (QoS). This is a challenging task because multimedia applications typically produce huge volumes of data requiring high transmission rates and extensive processing; the high data transmission rate of WMSNs usually leads to congestion, which in turn reduces the Quality of Service (QoS) of multimedia applications. To address this challenge, This paper proposes the Neural Control Exponential Weight of Priority Based Rate Control (NEWPBRC) algorithm for adjusting the node transmission rate and facilitate the problem of congestion occur in WMSNs. The proposed algorithm combines Neural Network Controller (NC) with the Exponential Weight of Priority Based Rate Control (EWPBRC) algorithms. The NC controller can calculate the appropriate weight parameter λ in the Exponential Weight (EW) algorithm for estimating the output transmission rate of the sink node, and then ,on the basis of the priority of each child node , an appropriate transmission rate is assigned . The proposed algorithm can support four different traffic classes namely, Real Time traffic class (RT class); High priority, Non Real-Time traffic class (NRT1 class); Medium priority, Non Real-Time traffic class (NRT2 class); and Low priority, Non Real-Time traffic class (NRT3 class). Simulation result shows that the proposed algorithm can effectively reduce congestion and enhance the transmission rate. Furthermore, the proposed algorithm can enhance Quality of Service (QoS) by achieve better throughput, and reduced the transmission delay and loss probability.

Keywords:-wireless multimedia sensor network; congestion control; QoS; neural network.

أولوية معدل انتقال مبني على السيطرة مع وحدة تحكم الشبكة العصبية في شبكات الا ستشعار الاسلكية ذات الوسائط المتعددة

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الخلاصة

شبكات الاستشعار اللاسلكية ذات الوسائط المتعددة هي شبكات مترابطة لاسلكيا بمجموعة من عقد الاستشعار المزودة بأجهزة الوسائط المتعددة، مثل الكاميرات و الميكروفونات .وبالتالي فإن هذة الشبكات لديها القدرة على نقل البيانات والوسائط المتعددة، مثل الفيديو والصوت ، الصور الثابتة ، والبيانات العددية من البيئة .معظم تطبيقات شبكات الاستشعار اللاسلكية ذات الوسائط المتعددة تتطلب إيصال المعلومات الوسائط المتعددة مع مستوى معين من جودة الخدمة . هذه هي مهمة صعبة لأن تطبيقات الوسائط المتعددة عادة ما تنتج كميات ضخمة من البيانات التي تتطلب معدلات نقل عالية ومعالجة واسعة النطاق ، معدل نقل البيانات السريع في شبكات الاستشعار اللاسلكية ذات الوسائط المتعددة عادة ما يؤدي إلى الازدحام ، والذي بدوره يقلل من جودة الخدمة (QoS) في تطبيقات الوسائط المتعددة. ولمواجهة هذا التحدي، تم اقتراح خوارزمية (NEWPBRC)تهدف لضبط معدل ارسال العقدة وتقليل مشكلة الازدحام الذي يحدث في شبكات الاستشعار اللاسلكية ذات الوسائط المتعددة . الخوارزمية المقترحة تجمع بين وحدة تحكم الشبكة العصبية (NC) مع خوارزميات (EWPBRC). وحدة تحكم الشبكة العصبية (NC) يمكنها حساب القيمة المناسبة لمعامل الوزن (λ) المستخدم في خوارزمية الوزن الاسي (EW) لتخمين معدل الارسال الخارج من العقدة الاساسية، ومن ثم، على أساس أولوية كل عقدة تابعة، يتم تعيين معدل ارسال مناسب لها . الخوارزمية المقترحة يمكن أن تدعم أربع اصناف مرور مختلفة وهي ، صنف مرور وقت حقيقي (RT)؛ صنف مرور وقت غير حقيقي , أولوية عالية (NRT1), صنف مرور وقت غير حقيقي , أولوية متوسطة (NRT2) , صنف مرور وقت غير حقيقي , أولوية منخفضة (NRT3) .النتائج العملية اظهرت أن الخوارزمية المقترحة يمكن أن تقلل بشكل فعال الازدحام وتحسن معدل ارسال البينات. وعلاوة على ذلك الخوارزمية المقترحة ، يمكن أن تعزز جودة الخدمة (QoS) من خلال تحقيق إنتاجية أفضل ، وتقليل تأخير الارسال لتجنب احتمالية فقدان الحزم.

الكلمات الرئيسية: شبكات الاستشعار ذات الوسائط المتعددة, التحكم في الازدحام؛ جودة الخدمة؛ الشبكات العصبية.

1. INTRODUCTION

Most of the research before in the Wireless Sensor Network (WSN) is concerned with scalar sensor networks that measure physical phenomena, such as pressure, temperature, humidity, or location of objects that can be conveyed through low-bandwidth and delay-tolerant data streams. Recently, the focus is shifting toward research aimed to enable delivery of multimedia content, such as audio and video streams, as well as scalar data. This effort resulted in distributed networked systems, referred as Wireless Multimedia Sensor Networks (WMSNs**), Akyildiz, et al.,2007.** WMSNs are set of sensor nodes, whereby the nodes are equipped with multimedia devices such as cameras, and microphones. Thus a WMSN will have the capability to transmit multimedia data, such as still pictures, stream video, voice, animal sounds, and monitoring data. One important requirement of applications in WMSNs is low delay bounds. Furthermore, some applications of WMSNs need relative resilience to losses. WMSNs can support different types of traffic classes, **Akyildiz, et al.,2007.**

There are many different resource constraints in WMSNs involving energy, bandwidth, memory, buffer size and processing capability .Given the physically small nature of the sensors, and that multimedia applications typically produce huge volumes of data requiring high transmission rates and extensive processing, this may cause congestion in the sensor nodes. Thus, developing protocols, algorithms and architectures to maximize the network lifetime while satisfying the quality of service (QoS) requirements of the applications represents a critical problem. In most WSN and WMSN applications, traffic mainly flows from a large number of sensor nodes to a base station (sink) node, **Akyildiz, et al., 2002.**

Congestion control is an important issue in transport protocols. Congestion is also a difficult problem in wireless sensor networks. It not only wastes the scarce energy due to a large number of retransmissions and packet drops, but also hampers the event detection reliability. Congestion in WSNs and WMSNs has a direct impact on energy efficiency and application, **QoS Ee ,** and **Bajcsy, 2004.** Usually, congestion occurs in the bottleneck since it receives more data than it is capable of sending out. In this situation, packets will be queued and sometimes get dropped. As a consequence, response time will increase which causes throughput to be degraded, **Samiullah,** and **Karim, 2011**.

Two types of congestion could occur in sensor network, as show in **Fig. 1** and **Fig.2.** The first type is Node –Level congestion that is common in conventional network.it is caused by buffer overflow in the node and can result in packet loss, and increased queuing delay, **Malar, 2010.** Not only can packet loss degrade reliability and application QoS, but it can also waste the limited node energy and degrade link utilization. In each sensor node, when the packet-arrival rate exceeds the packet service rate, buffer overflow may occur. This is more likely to occur at sensor nodes close to the sink, as they usually carry more combined upstream traffic, **Yaghmaee,** and **Adjeroh, 2008**. The second type is Link-Level congestion, which occurs in wireless transmission and occurs when the nodes are in the same utilization channel, for example, Carrier Sense Multiple Access with Collision Detection (CSMA/CD). Such a situation occurs when multiple active nodes perform access on the same channel and collision is then the result, **Wan, and Siphon, 2005.**

2. RELATED WORK

Various congestion control techniques have been studied for wireless multimedia sensor networks .the congestion control mechanisms all have the same basic objective: they all try to detect congestion, notify the other nodes of the congestion status, and reduce the congestion and/or its impact using rate adjustment algorithms. **Wang, et al.,2007**, proposed Priority Based Congestion Control Protocol (PCCP). **Yaghmaee, and Adjeroh, 2009**, proposed Priority Based Rate Control Algorithm (PBRC) used for congestion control and service differentiation in WMSNs. **Chen, and Lai, 2012**, proposed an algorithm where a Fuzzy Logical Controller (FLC) is used to estimate the output transmission rate of the sink node. The FLC is associated with the Exponential Weight (EW) algorithm for selecting the appropriate weight parameter, and then, on the basis of the priority of each child node, an appropriate transmission rate is assigned. **Pawar**l, and **Kasliwal, 2012**, proposed a QoS-based sensory Media Access Control (MAC) protocol, which does not only adapts to application oriented QoS, but also attempts to conserve energy without violating QoS-constraints. proposed MAC layer protocol for WMSNs satisfy feature like Maximize network throughput, Enhance transmission reliability, and Minimize control overhead, be energy-efficient, Guarantee a certain level of QoS.

3. THE NETWORK MODEL

Fig. 3 shows a simplified experimental model for WMSN .This network model consist of ten nodes, nine sensor nodes, one sink node and the Base Station (BS). The locations of sensor nodes and the base station are fixed. Each sensor node has the knowledge of its own geographic location and the locations of its 1-hop neighbor nodes. Each of the nodes can sense different types of data at the same time and sends those to BS. For each node in the network, there is a single path to reach to the BS.

In this network model node may generate different types of traffic .for example node 9 produces only NRT3 traffic, node 6 produces two type of traffic NRT1 and NRT2, while node 8 produces four type of traffic RT, NRT1, NRT2, and NRT3.

The queuing model of each node is shown in **Fig.4**. Each traffic class well be buffered in a separate queue, To discriminate traffic classes from each other, the wireless node adds a traffic class identifier to its local sensor packets; hence, when a data packet enters a transmission traffic classifier, the data type will be classified to enter the respective queue that it belongs to, then priority queue scheduler has been provisioned to schedule the diverse traffic with different priority from the priority queues.

4. PROPOSED NEWPBRC ALGORITHM

Fig. 5 shows the block diagram of the proposed algorithm which is called Neural controller Exponential Weight Priority-Based Rate Control (NEWPBRC), for the proposed algorithm which combines the Neural Controller (NC) with the Exponential Weight of Priority-Based Rate Control (EWPBRC) algorithm. The NC controller is used to adjust the weight parameter λ in the EWPBRC algorithm to obtain the optimal $r(sink)_{out}$ as shown in **Fig. 5**, where $r(sink)_{out}$ denotes as the rate of the output of the sink node. And $r(sink)_{in}$ is the sum of input transmission rates for all the childe nodes for transmission data to the sink node. Furthermore, the transmission rate adjusts according to the priority of each child node.

In the proposed algorithm, The NC controller follow $r(sink)_{in}$ to estimate the output transmission rate $r(sink)_{out}$ of the sink node, where $r(sink)_{out}$ is the transmission rate for the sink node to transmit data to the BS. In addition, the transmission rate of the node is adjusted according to the priority of the data type and the geographical location of the node .The structure of the proposed algorithm that contains NC controller is based on neural network which is shown in **Fig. 6** .The Feed Forward neural network is constructed in three layers. One unit in the input layer, four units in hidden layer, and one unit in the output layers .the output signal from the controller is the weight parameter (λ) that is used in EWPBRC algorithm. The activation function of the hidden layer is sigmoid. In **Fig. 6** ,W denotes the connection weights between the input layer and the hidden layer , and V denotes the connection weights between the hidden layer and the output layer .The NC controller is trained off-line using The Back Propagation (BP) training algorithm .The simulation of BP algorithm is done using MATLAB program . During the Training process weights in NC controller are adapted to optimize the controller response.

The congestion control unit in the proposed NEWPBRC algorithm is shown in **Fig. 7**, when input rate $r(sink)_{in}$ passes through the CDU unit, calculate error, and then after the adjustment of the output transmission rate by the NEWPBRC controller and RMU unit, a new rate is generated to adjust the rate for transmitting from the sink node to the BS and the transmission rate for transmitting from all the child nodes to the sink node.

5 . RATE MANAGEMENT ALGORITHM

NEWPBRC algorithm used for adjustment the transmission rate while congestion occurs. This algorithm can be divided into three steps:

Step 1: Computing the new output transmission rate of sink node.

The error e is used as the input variable to the NC controller. E (t) is the error between $r(sink)_{in}(t)$ and $r(sink)_{out}(t)$ at time instant t, which is represented by

$$e(t) = r(sink)_{in}(t) - r(sink)_{out}(t) \quad (1)$$

The NC controller used to adjust weight parameter λ of the EW algorithm ,calculation of weight parameter λ is given by :

$$net\ 1 = (e * w) \quad (2)$$

$$fnet1 = f_1 .(net1) \quad (3)$$

$$net\ 2 = (fnet1 * v) \quad (4)$$

$$\lambda = f_2. (net\ 2) \quad (5)$$

Where λ is a constant, $0 \le \lambda \le 1$. f_1 sigmoid activation function and f_2 is linear activation function, w and v are connection weights .

Using the transmission rates of $r(sink)_{in}(t)$ and $r(sink)_{out}$ (t) at time instant t, and from optimal value of weight parameter λ, we can calculated the $r(sink)_{out}$ (t+1) output transmission rate at time instant t+1 :

$$r(sink)_{out}(t+1) = r(sink)_{in}(t).(1-\lambda) + \lambda . r(sink)_{out}(t) \quad (6)$$

Step 2: Calculating the new output transmission rate for child node.

In WMSNs, based on the functionality, different types of sensor node will be equipped, and a node will be deployed at a related geographical location according to the different levels of importance.

In data transmission, on the basis of the geographical location, an appropriate priority and transmission rate will be given. $P(i)_{GEO}$ is the geographical location priority of node i. The total priorities $TP(i)$ of node i are the traffic class priority $P(i)_{TRC}$ and geographical location priority $P(i)_{GEO}$, defined as follows:

$$TP(i) = P(i)_{TRC} . P(i)_{GEO} \quad (7)$$

Let C(i) is the set of child nodes of node i; the global priority $GP(i)$ is defined as the sum of priorities of all nodes in sub tree node *i*. the global priority $GP(i)$ is given by:

$$GP(i) = \sum_{k \in c(i)} GP(k) + TP(i) \quad (8)$$

If node i doesn't have any child nodes, Then its global priority will be equal to its total priority $TP(i)$ value.

Note that global priority $GP(i)$ is calculated only for active traffic sources .On the other hand ,if the traffic sources is not active ,then the value of total priority $TP(i)$ is set to zero. This ensures that the algorithm will share the existing capacity only between active nodes.

$GP(sink)$ is the sum of global priorities of the sink node, C(Sink) is the set of all the child nodes with the sink as their parent, and $GP(sink)$ is the sum of the priorities of all the nodes, and is represented as follows:

$$GP(sink) = \sum_{k \in c(sink)} GP\ (k) \tag{9}$$

To calculate the optimal output transmission rate $r(i)_{out}$ of node i, $r(i)_{out}$ is calculated on the basis of the distribution of the output transmission rate $r(sink)_{out}$ from the sink node to node i according to the proportion between the global priority of child node $GP(i)$ and the global priority of the sink node $GP(sink)$:

$$r(i)_{out} = r(sink)_{out} \cdot \frac{GP(i)}{GP(sink)} \tag{10}$$

Step 3: Computing a new output transmission rate for each parent node.

$r(i)_{in}$ is the input transmission rate of node i, which is obtained through the summation of the $r(k)_{out}$ of the connected child nodes, and $r(i)_{in}$ is calculated as follows:

$$r(i)_{in} = \sum_{k \in c(i)} r(k)_{out} \tag{11}$$

where C(i) is the set of node i, and $r(k)_{out}$ represents the output rate of the k^{th} child of parent node i. $\Delta\, r(i)$ is the transmission rate difference of node i and is as follows:

$$\Delta\, r(i) = \mu \,.\, r(i)_{out} - r(i)_{in} \tag{12}$$

where μ is a constant close to 1.

Node i generates a new transmission rate to be distributed to all the child node k output transmission rates; this is calculated as follows:

$$r(i)_{out} = r(k)_{out} \cdot \frac{GP(i)}{GP(sink)} \tag{13}$$

Fig. 8 explain the rate management process of the NEWPBRC algorithm.

6. SIMULATION RESULTS

The proposed algorithm is implemented using the Network simulator 2 (NS-2) [www.isi.edu/nsnam/ns]. The NS-2 simulation environment is a flexible tool for network engineers to investigate how various algorithms perform with different configurations and topologies. To evaluate the performance of the proposed algorithm, three important parameters are considered. These parameters are throughput, delay, and packet loss probability. The simulation model consists of ten wireless multimedia sensor nodes, nine multimedia sensor node, one sink node and BS. The transmission route of that model is a single-path transmission. The transmission data collected by multimedia sensor nodes are generated randomly, All senders transmit data traffic to a single sink node. In the simulation model, there are four types of traffic class, namely RT, NRT1, NRT2 and NRT3. The simulated traffic is Pareto [www.wikipedia.org]. Each packet size is 500 bytes, the buffer size of each child node is set up as 50 packets, and the buffer size of the sink node is 100 packets. All multimedia sensor nodes start to send their data at the start of the simulation rounds and stop at the end of simulation rounds. The simulation rounds are 100 seconds. The performance measured after 30 simulation rounds. The channel capacity of each multimedia sensor node is set to the same value: 2 Mbps. The combination of traffic classes that each node could have in the simulation model is shown in Table (1) .where the symbol PV indicates Priority Value of traffic.

Assuming that all sensor nodes have the same geographical priority equal to 1. Suppose the assigned priority for RT, NRT1, NRT2, and NRT3 classes are equal to 4, 3, 2 and 1, respectively. For example , the sensor node 8 which has all traffic classes , the traffic class priority , $P(8)_{TRC}$ is 10 (4 + 3 + 2 + 1 = 10) ,while for sensor node 9 which has only NRT3 traffic classes, the traffic class priority , $P(9)_{TRC}$ is 1 .The performance of the proposed NEWPBRC algorithm is compared with FEWPBRC and EWPBRC algorithms. The performance is evaluated mainly according to the following metrics:

1- Throughput : measured in terms of number of packets received.
2- Sink Delay : is the time for the sink node to transmit data to BS.
3- End to End Delay: the packet transmission time between sources and sink node.
4- Packet Loss probability : it is a percent between number of packets lost in the network and number of packet generated by the sensing nodes .

Fig. 9 shows a comparison for the output transmission rate $r(sink)_{out}$ of three algorithms, namely the EWPBRC algorithm with λ = 0.5, the FEWPBRC algorithm, and the NEWPBRC algorithm. From the simulation results, It can be seen that the proposed algorithm has a slightly better throughput than FEWPBRC algorithm and EWPBRC algorithm**. Fig.10** shows a comparison for the delay of sink node of the EWPBRC algorithm with λ = 0.5,the FEWPBRC algorithm, and the NEWPBRC algorithm . Simulation result show that both the FEWPBRC and the NEWPBRC algorithm have average delay smaller than that of EWPBRC algorithm .The proposed algorithm has the shortest average delay time. **Fig. 11** shows a comparison for the end to end delay of the EWPBRC algorithm with λ = 0.5,and the NEWPBRC algorithm. **Fig. 12** shows a comparison for the loss probability of three algorithms, namely, the EWPBRC algorithm with λ = 0.5, the FEWPBRC algorithm, and the NEWPBRC algorithm .From the simulation result , it can be seen that the proposed algorithm has the lowest loss probability .

7. CONCLUSIONS

NEWPBRC algorithm is implemented in WMSN using NS2 simulator .then take average of performance parameters to get a more accurate result. The proposed algorithm enhancement the transmission rate and tries to avoid congestion, resulting to enhance the Performance of WMSN. The proposed algorithm provides good QoS in terms of minimizing delay and packet loss ratio and enhances the throughput of the network. The Average throughput achieved by NEWPBRC algorithm is slight better than of FEWPBRC algorithm. The Average sink delay achieved by the proposed algorithm is low by (13%) than that achieved by FEWPBRC algorithm. The proposed algorithm can be (4.61%) less average loss probability than FEWPBRC algorithm.

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8. LIST OF SYMBOLS

PV	Priority value
W	*Weight matrix*
Thr	Throughput
Del	Delay
C(S)	The number of the child nodes for a parent node S
e	Error
λ	Weight parameter
$r(sink)_{in}$	Input transmission rate to sink node
$r(sink)_{out}$	Output transmission rate of sink node
$P(i)_{TRC}$	Traffic class priority
$P(i)_{GEO}$	Geographical priority
$SP(i)_j$	The traffic source priority j in sensor node i
e (t)	The error between $r(sink)_{in}(t)$ and $r(sink)_{out}$ (t) at time instant t
$r(sink)_{out}$ (t+1)	Output transmission rate at time instant t+1
TP(i)	The total priorities of node i
GP(i)	The global priority
GP(sink)	The sum of global priorities of the sink node
C(Sink)	The set of all the child nodes with the sink as their parent
$r(i)_{out}$	The optimal output transmission rate of node i
$r(i)_{in}$	The input transmission rate of node i
$r(k)_{out}$	The output rate of the kth child of parent node i
$\Delta r(i)$	The transmission rate difference of node i
μ	Constant close to 1

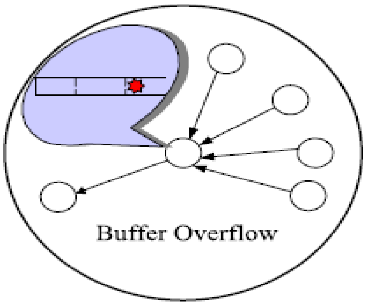

Figure1. Node–level congestion **Malar, 2010.**

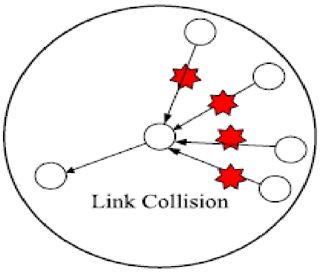

Figure2. Link – level congestion **Malar,2010.**

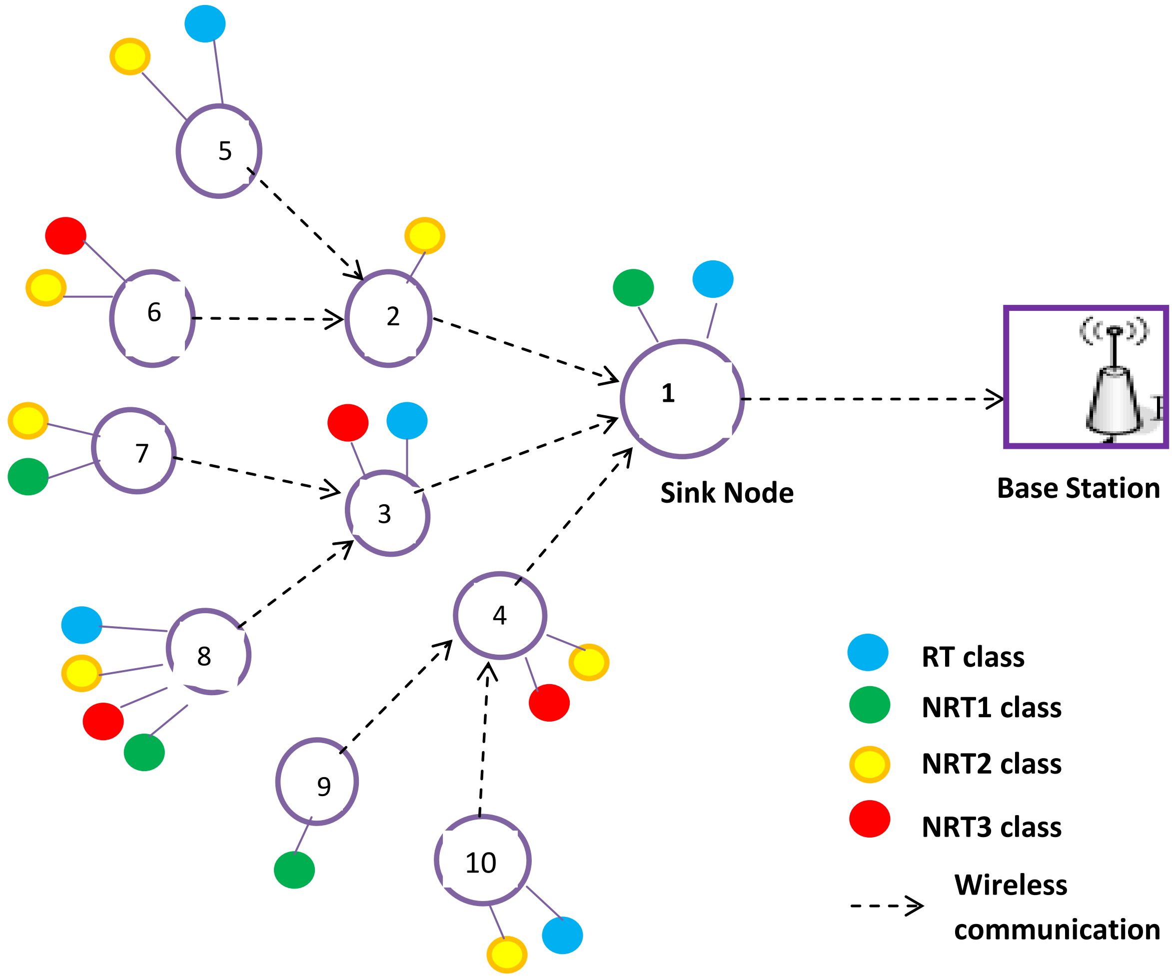

Figure 3. WMSN model **Chen, and Lai, 2012.**

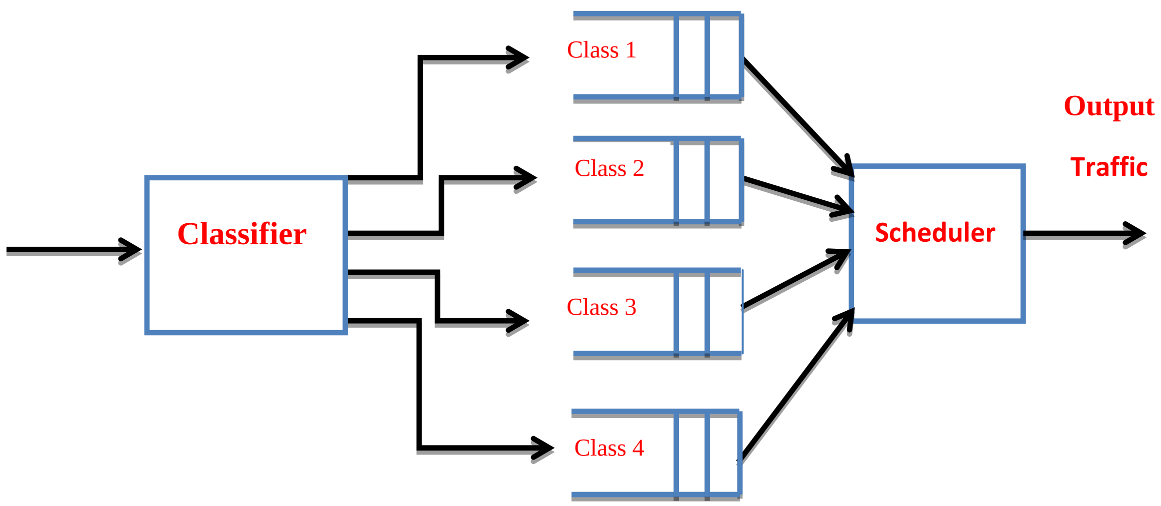

Figure 4. Queue model for each sensor node **Chen, and Lai, 2012**.

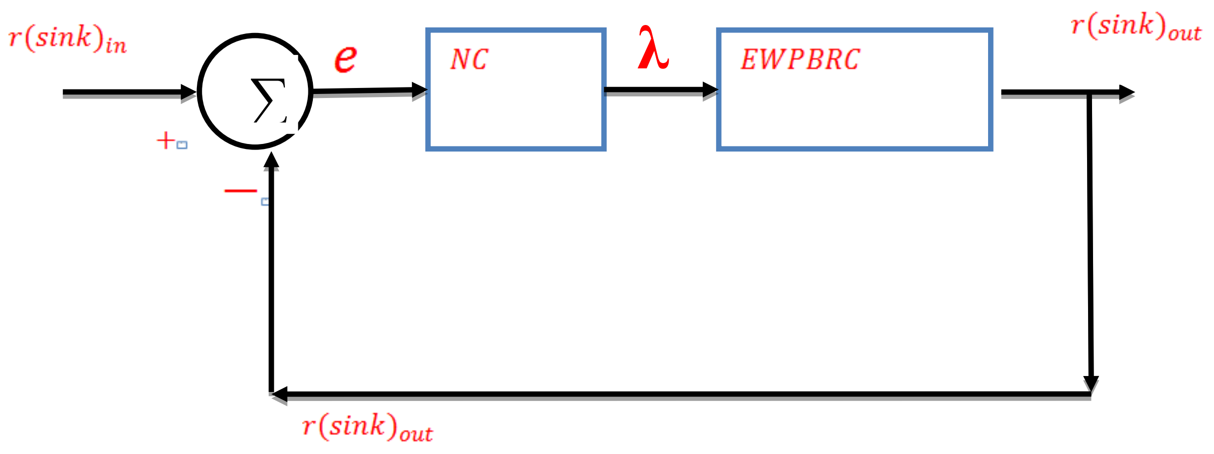

Figure 5. Block diagram of NEWPBRC algorithm.

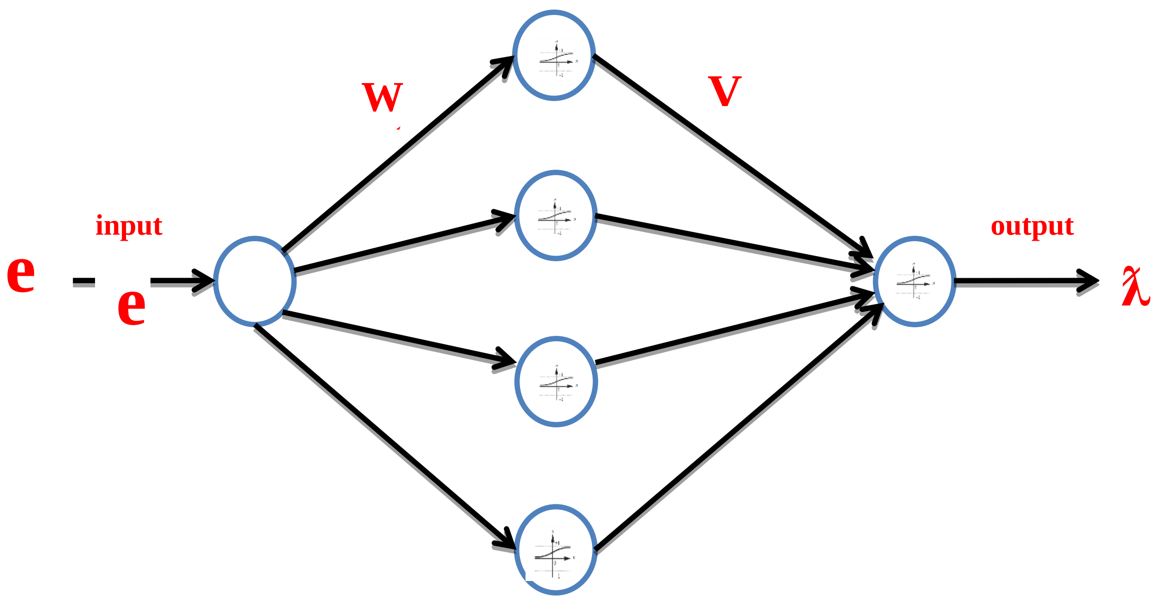

Figure 6. Structure of NC controller .

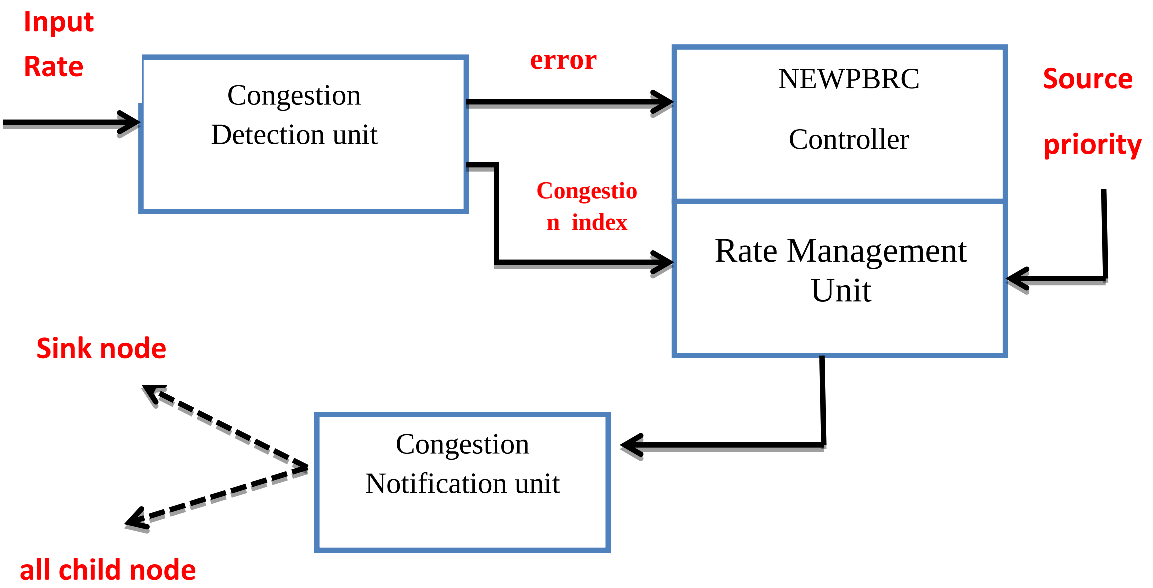

Figure 7. Structure of NEWPBRC congestion control unit.

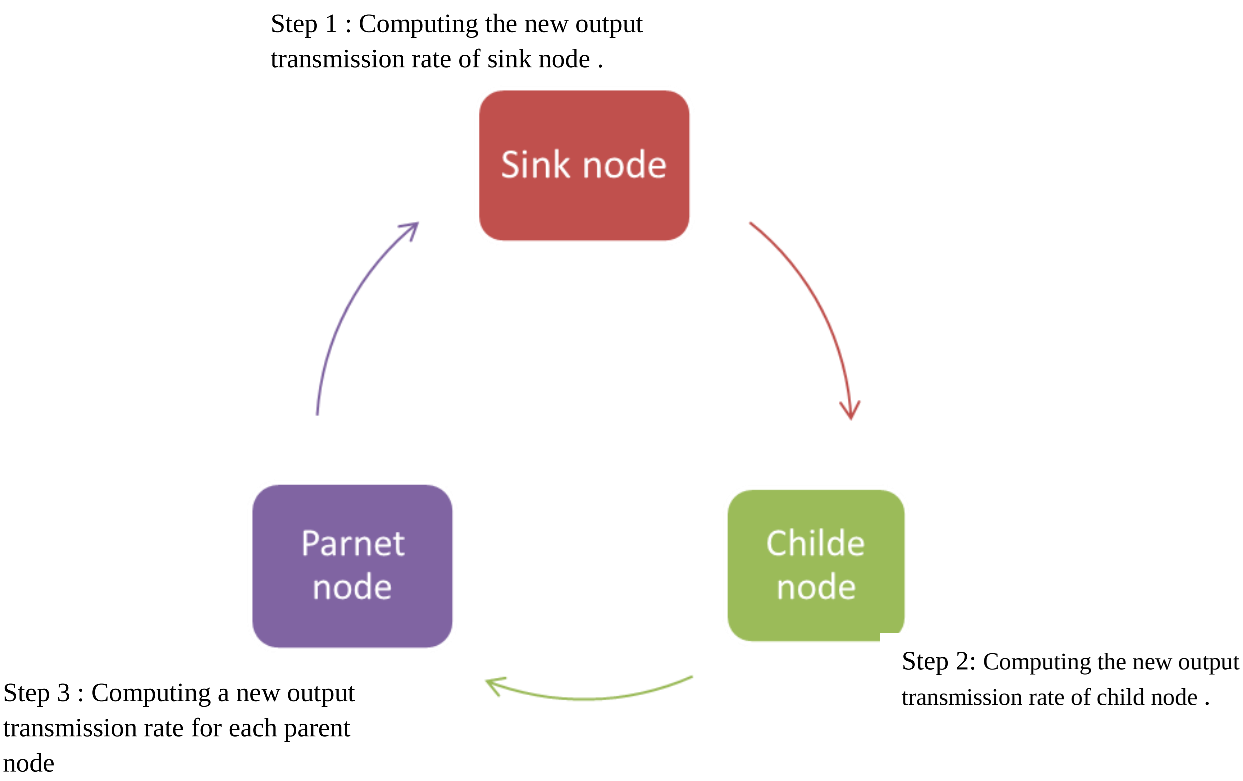

Figure 8. Rate management for NEWPBRC algorithm.

Table 1. The state of traffic classes in each sensor node .

Sensor node No.	RT (PV = 4)	NRT 1 (PV = 3)	NRT 2 (PV= 2)	NRT 3 (PV = 1)	Traffic Priority
1	ON	OFF	OFF	ON	5
2	OFF	ON	OFF	OFF	3
3	ON	OFF	ON	OFF	6
4	OFF	ON	ON	OFF	5
5	ON	ON	OFF	OFF	7
6	OFF	ON	ON	OFF	5
7	OFF	ON	OFF	ON	4
8	ON	ON	ON	ON	10
9	OFF	OFF	OFF	ON	1
10	ON	ON	OFF	OFF	7

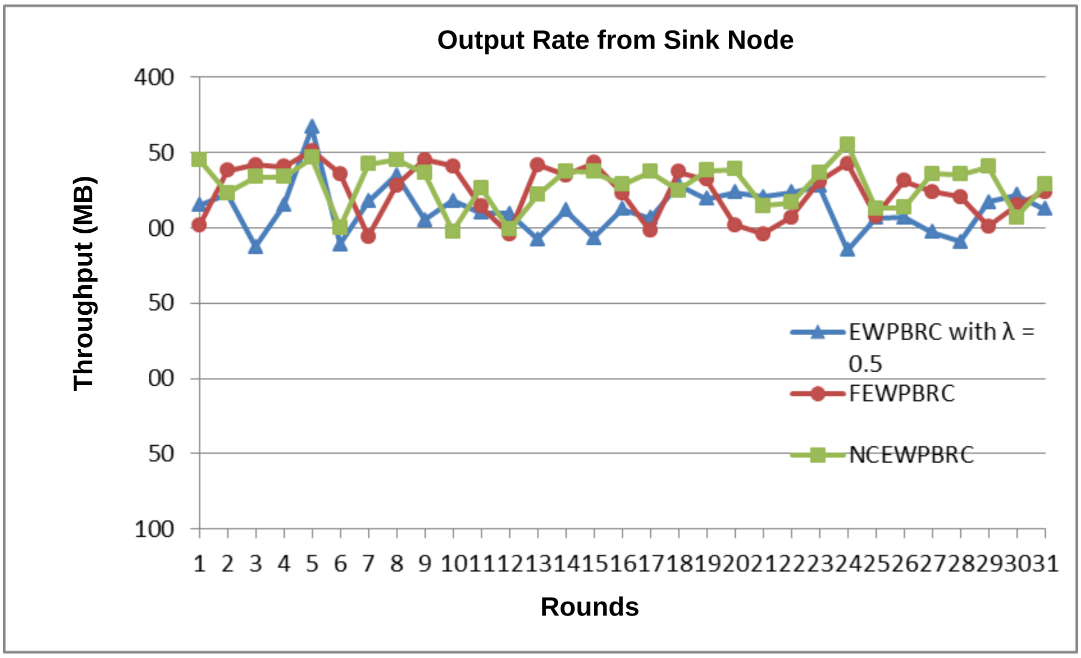

Figure 9. Compared performance of different algorithms for output transmission rate $r(\text{sink})_{out}$.

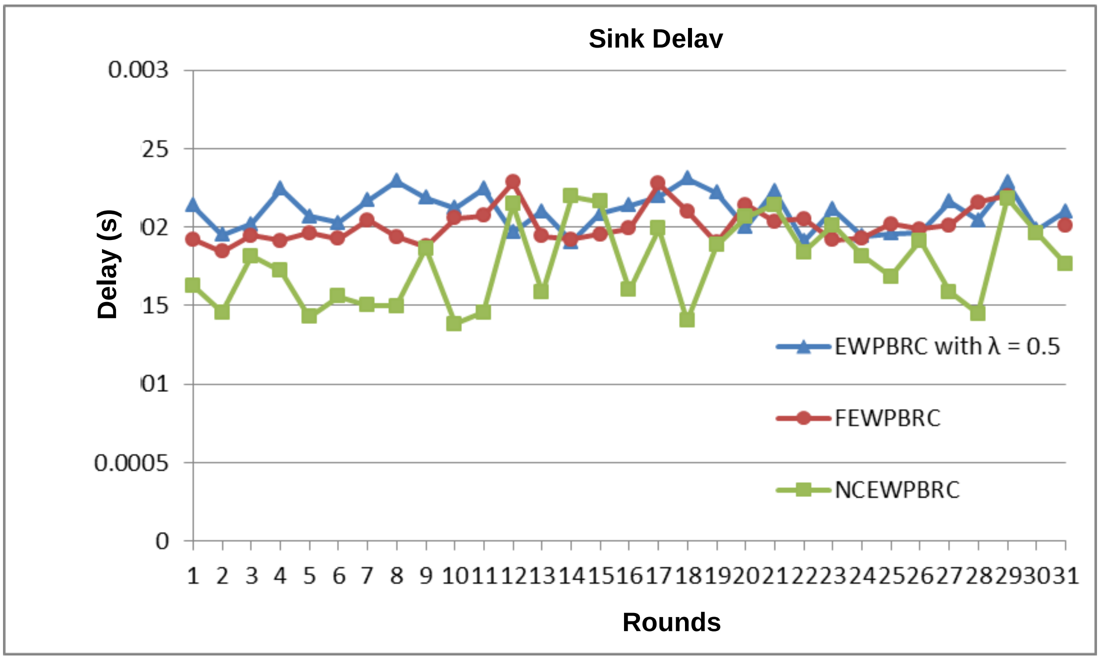

Figure 10. Compared the delay of sink node for different algorithms.

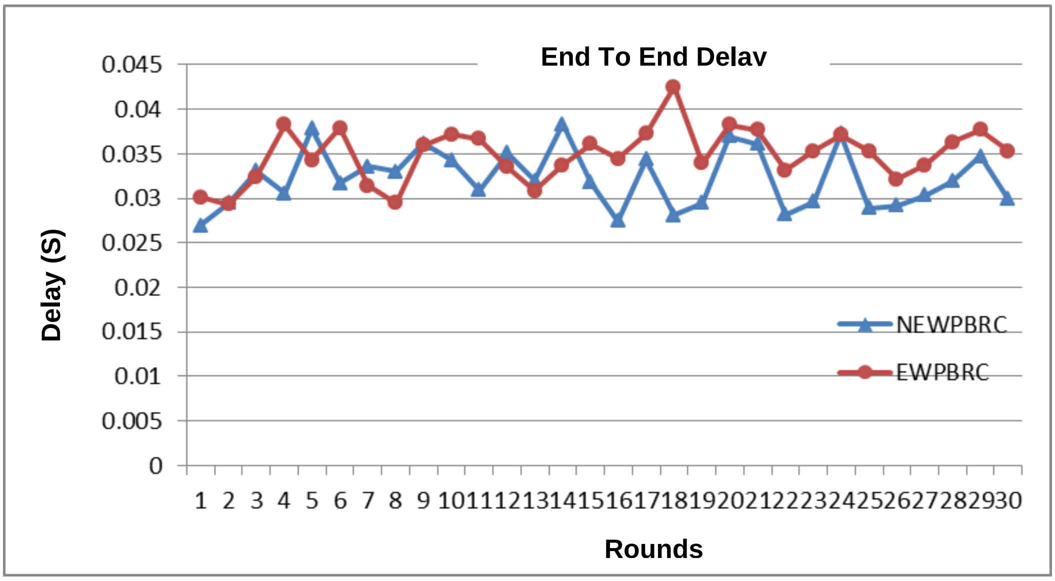

Figure 11. Comparison of end to end delay for different algorithms.

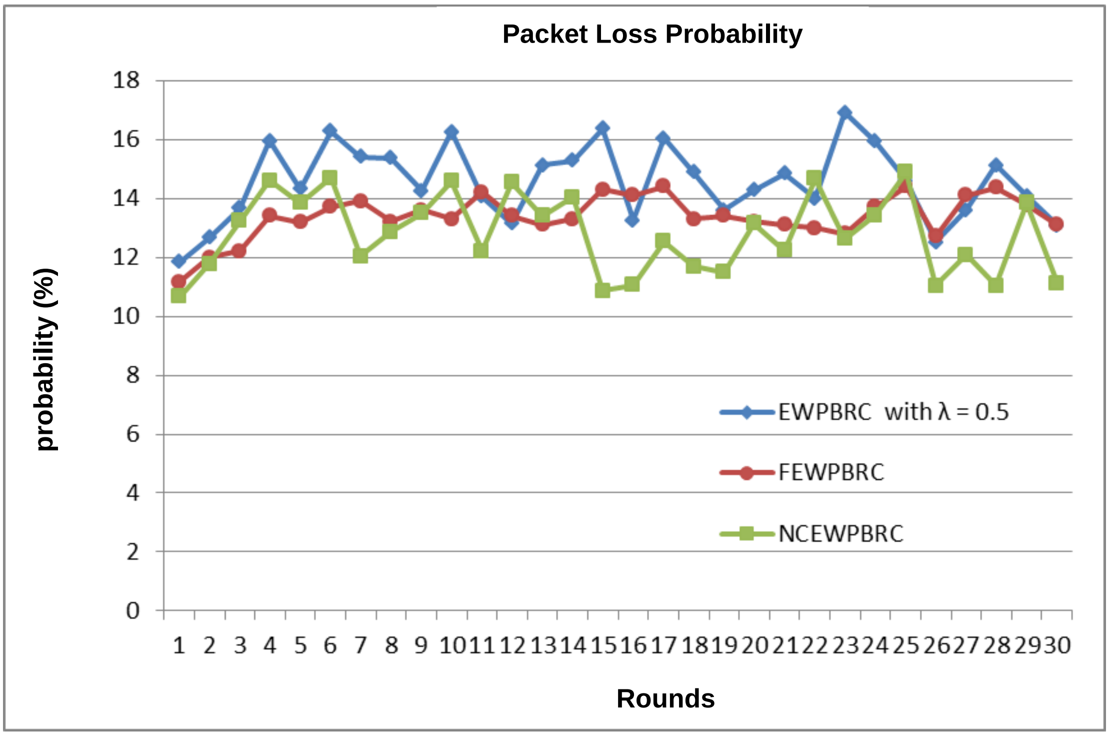

Figure 12. Compared of loss probability for different algorithms.