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Daly Analysis for WiMax under balanced and unbalanced traffic conditions in fixed priorities between stations

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ABSTRACT *:* *Broadband Wireless Access (BWA) systems offer a solution for broadband access and high data rate transmission of multimedia services with distinct Quality-of-Service (QoS) requirement through a wireless medium. The IEEE802.16 standard does not specify how to efficiently schedule the traffic related to different applications in order to meet their specific requirements. In this paper, we present a modified scheme which is based on a Reservation Priority Access Control (RPAC) using TDD allocation approach, and the behavior of this reservation scheme is analyzed and evaluated under balanced and unbalanced traffic conditions in fixed priorities between stations.*

KEYWORDS - *Broadband Wireless Access, Quality-of-Service, Reservation Priority Access Control, Downlink Channel*

I. INTRODUCTION

The Broadband Wireless Access (BWA) is a technology proposed to offer wireless access to network stations in a broadband metropolitan area environment. These networks are designed to operate at high data rates and to deal with several applications, resulting in different types of traffic profiles and demands. Therefore, the system is required to work with various types of real-time and non-real-time service classes, with different traffic characteristics and quality of service (QoS) guarantees. In [1] , a new MAC scheme for BWA, incorporating a scheduling mechanism based on message and/or station priorities, was proposed as an alternative protocol to the IEEE 802.16 Standard [3]. However, only a fixed priority approach to service differentiation among terminals was used.In this paper, we propose an extention to the MAC protocol described in [1], with a unbalanced traffic conditions in fixed priorities between stations in the network. Moreover, we developed a simulation model to compare the analytical results under balanced and unbalanced traffic conditions and the simulation results exposed here.The remainder of this paper is organized as follows. Section II gives a short description of IEEE 802.16 standard.The proposed protocol is described in Section III. An analytical model, which allow to obtain the average message waiting time for different priority classes, is provided in section IV. Section V presents some numerical results and the paper is concluded with a few discussions concerning the proposal in Section VI.

II. IEEE 802.16 STANDARD

A- PHY and MAC Layers

In the basic architecture there are one Base Station (BS), and one or more Subscriber Stations (SSs). Transmissions are assumed to take place through two independent channels: a Downlink Channel (DL) from the BS to the SSs, and an Uplink Channel (UL) from the SSs to the BS. Hence, there is no contention associated with the the DL channel, while the UL channel must be shared by the SSs through the use of some multiple access control protocol. During the DL, only the BS transmits in broadcast to all the SSs. The BS determines the number of slots to be allocated for each SS in the UL, and broadcast this information in an UL-MAP message at the beginning of each frame. The stations transmit their data in predefined time slots as indicated in the UL-MAP. A scheduling module for the UL is necessary to be kept in the BS in order to determine the transmission opportunities using the bandwidth requests (BW-Request) sent by the SSs. Figure 1 illustrates the structure of the MAC frame.

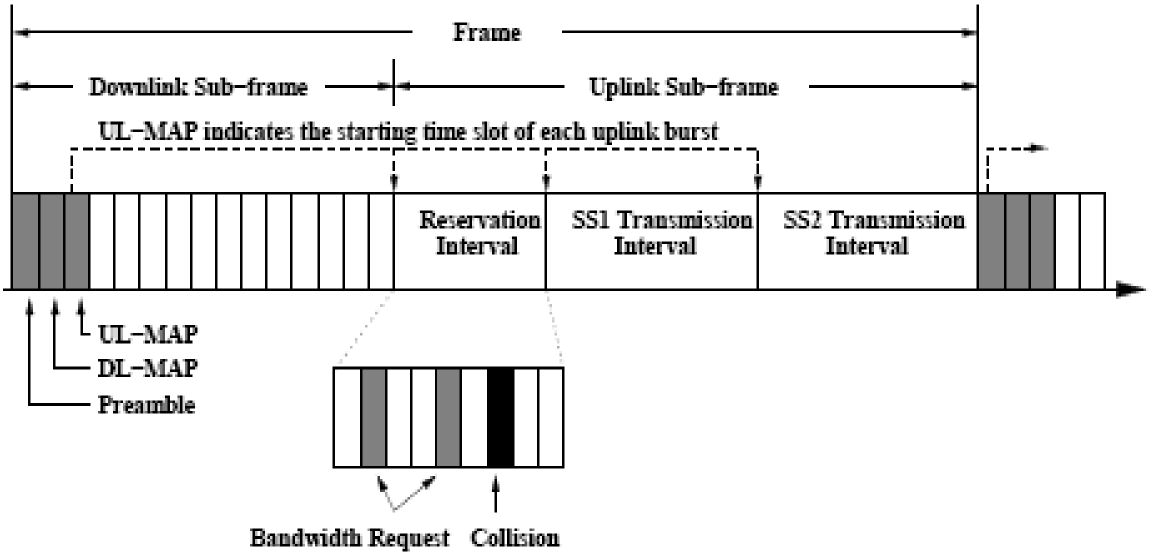


Fig.1. MAC frame structure

B- QoS Architecture

The IEEE 802.16 supports many traffic types (data, voice, video) with different QoS requirements. The standard defines four types of data flows, each one associated with distinct applications and QoS requirements [2]:

1. Unsolicited Grant Service (UGS): for applications with constant bandwidth allocation requirements.
2. Real-Time Polling Service (rtPS): for applications with specific bandwith requirements and maximum acceptable delay.
3. Non-Real-Time Polling Service (nrtPS): for applications with a minimum bandwidth allocation requirements, that are intolerant to delay.
4. Best Effort Service (BE): for applications without bandwidth allocation requirements, that receive the remaining bandwidth after the allocation to the three previous types of services. Fig. 2 shows the QoS architecture present in 802.16. The UL packet scheduling (UPS) module controls all the packet transmissions in the UL. As the protocol is connection-oriented, the application should establish a connection between the BS and the associated service flow (UGS, rtPS, nrtPS or BE). The BS identifies the connections by assigning a unique Connection ID (CID) to each one. The 802.16 defines the signaling process for the establishment of a connection (Connection-Request and Connection-Response) between SS and BS, but does not specify the rules for admission control.

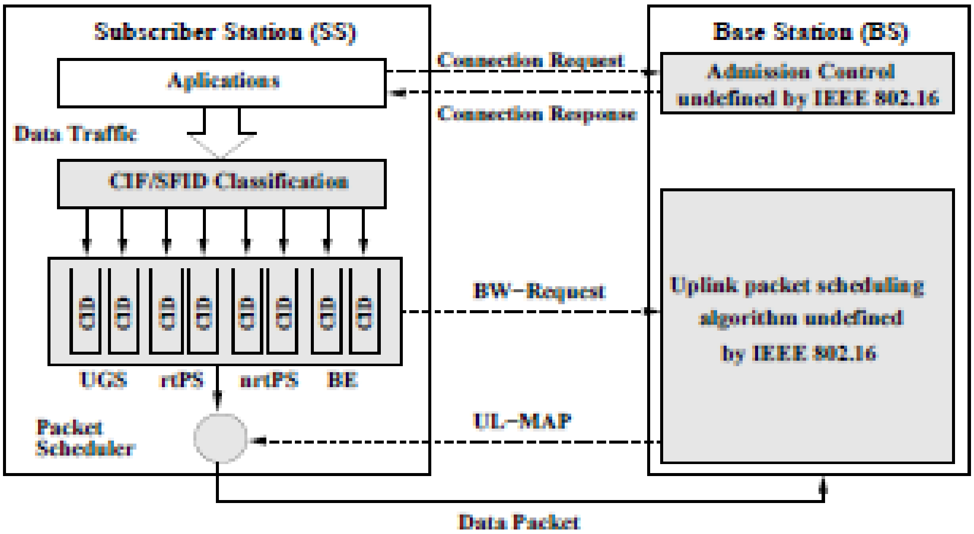


Fig.2 QoS Architecture of IEEE802.16

In summary, the IEEE 802.16 specifies: the signaling mechanism for information exchange between the BS and the SSs, as the connection configuration, BW-Request and UL-MAP; and the scheduling of UL for UGS traffic. The standard does not define: the scheduling of UL for rtPS, nrtPS and BE services; admission control and traffic policing.

III. PROPOSED PROTOCOL

In the paper, we use the TDD allocation scheme, and we will compare result for unbalanced traffic conditions with the results of the balanced traffic condition which were achieved in [1]. the authors proposed a new MAC protocol for IEEE802.16 that uses an access scheme called RPAC (Reservation-Priority Access Control), described in [3]. This access scheme incorporate a traffic scheduling mechanism based on messages and/or stations priorities, and a reservation period governed by a TDMA discipline with one time slot allocated per station in the network. The difference between the protocols described in [1] and [3] is that, in the former, the access scheme was reformulated and adapted to 802.16 MAC structure. The MAC frame structure for the proposed protocol is illustrated in Figure 3. Differently from the 802.16 standard, the frame lengths are not fixed in the proposed scheme. Basically, the length of each frame will depend upon the number of packets arriving to the stations in the previous frame. Reservation periods are located at the end of the UL sub-frame (not at the beginning as in 802.16). Those periods are used by each of the stations to inform the BS about the services for which a bandwidth reservation is being requested, as well as the number of packets to be transmitted for each of those services. After processing all the requests, the BS sends, in the DL sub-frame of the next frame, a UL-MAP with transmission opportunities to all reserved stations.

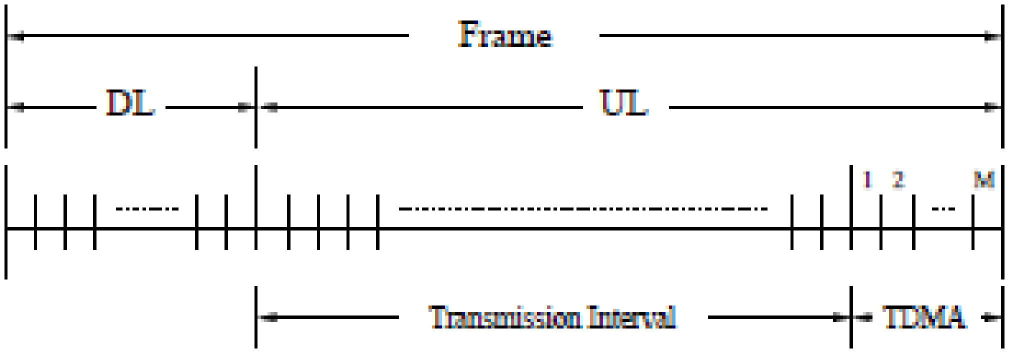


Fig 3. MAC Frame Structure for the Presented Scheme [1]

For analysis of the protocol, the activity in the channel can be seenas a sequence of reservation, downlink, and transmission intervals, where each pair of DL and UL constitutes a transmission cycle, as illustrated in Figure 4. It is important to note that there is a difference between the MAC frame and the transmission cycle, despite both having an equal size, because the reservation period is fixed. In fact, the n-th cycle is formed by the reservation period of (j−1)-st frame, plus the downlink and transmission intervals of the j-th frame. With this definition of the transmission cycles, the analytical approach described in [3] can be used for the analysis of the average waiting-time of the messages, as will be seen in Section IV. Referring to the picture in Figure 4, we define L_n^R ,$L_n^{DL} and\ L_n^T$ respectively, as the lengths (or duration, given by the number of slots) of the reservation, the downlink, and the transmission intervals in the n-th cycle. Thus,$L_n = L_n^R + L_n^{DL} + L_n^T$ represents the total length of the n-th cycle. Following the TDMA protocol, each reservation period is composed by M slots (L_n^R= M; n = 1, 2 ...), where M is the number of stations in the network. During this period, of duration of Mτ seconds, each station is associated to a single slot in a fixed manner.

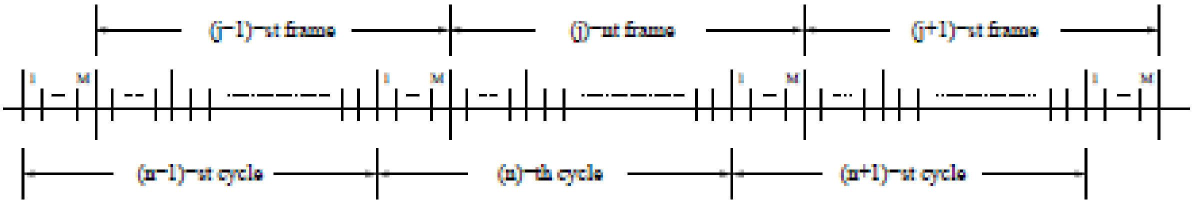
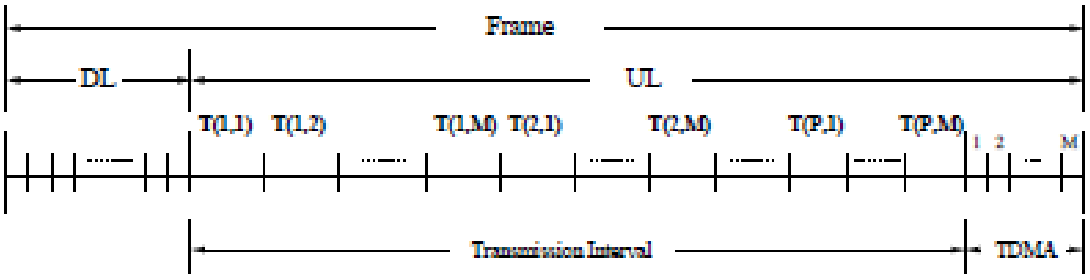


Fig 4. Consecutive Transmission Cycles.

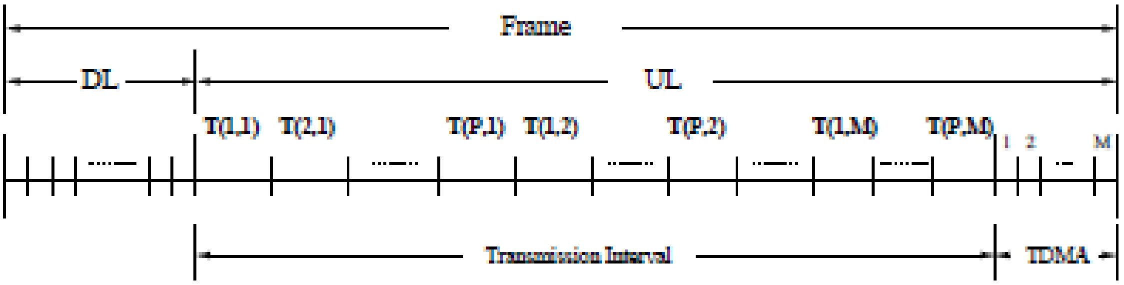
We note that the length of a current (say, the *n*-th) cycle will depend on the number of messages that arrived during the previous (say, the ($n - 1$)-st) cycle. This happens because request for the messages that arrived during the ($n-1$)-st cycle will be transmitted in the reservation period of the *n*-th cycle. After this period, the BS performs the centralized processing of the transmission opportunities and sends a UL-MAP in the DL sub-channel, still in the *n*-th cycle. Afterwards, the stations transmit their messages in the transmission interval of the same cycle, following the priorities established in the UL-MAP. Therefore, messages arriving during an ongoing cycle get transmitted only in the subsequent cycle. We propose a medium access protocol with priorities based on messages and/or stations, in accordance to the 802.16 protocol, that uses GPC or GPSS admissions. We assume that, following the reservation phase and the DL sub-frame, the channel is allocated to the stations following the sequence 1, 2, 3, ...,*M*. Thus, according to the priority rules used to determine the order in which the messages should be transmitted during the transmission period, the following versions of the protocol are considered:

- **Version I**, in which, for any *p*, *q 2 {*1, ..., *P}* such that *p* < *q*, all the class-*p* messages are transmitted before any messages of class *q*, independent of which station it belongs to. For messages belonging to the same class but in distinct stations, the order of the transmissions is according to the order in which the stations access the channel (first station 1 and last station *M*). For messages in the same station with the same class of priorities, the transmissions occur by order of arrival.
- **Version II**, in which, for any *i*, *j 2 {*1, ...,*M}* such that *i* < *j*, all the messages in station *i* are transmitted before any message in station *j*, independently of it‘s priority class. In any terminal, the messages are transmitted in accordance with their priority classes and in order of arrival, in the case of belonging to the same class; that is, at each station, the priority discipline HOL (Head-Of-the-Line) is applied with the highest priority assigned to class 1 and the lowest assigned to class *P*. The behavior of the channel, according to Versions I and II of the proposed protocol, is illustrated in Figures 5 and 6, respectively. Note that, in Version II, a higher priority station transmits all it‘s messages before one of lower priority. So, unlike Version I, it is possible that messages of lower priority are transmitted before messages with higher priorities. We observe that a rigid admission control carried by the BS and also by the SSs is necessary so that the heavy traffic of a specific class (or station) does not overload (and hog) the channel, affecting the response time of the others.



T(p,i) = time interval reserved for transmissions of class−p messages from station i;

Fig. 5. Version I of proposed protocol.



T(p,i) = time interval reserved for transmissions of class−p messages from station i;

Fig. 6. Version II of proposed protocol.

IV. ANALYTIC MODEL

The technique used to obtain the average waiting-time for the messages is similar to the method used in [4]. The analysis for Version I of the proposed scheme is introduced first, and then obtained results are adopted and used to extend our analysis to cover Version II. As defined in [1], the system considered has one BS and M (M ¸1) client stations (SSs), each of which has an infinite buffer-size and is already associated with the base station. The transmission channel is assumed to be error-free, with a transmission rate equal to C bit/s. In general, the messages generated at each station are composed of a random number of fixed units of data, called packets, each of which contains⍰$^{-1}$ bits. The transmission time of each packet is made equal to a time slot (τ). Therefore $\tau = 1/(\mu C)$. Messages arriving at each station belong to one of the different P classes and we assume that class-1 messages have the highest priority and class-P messages the lowest. Moreover, the arrival of messages is characterized by a Poisson point process, such that λ_i^p (messages per slot) is the average arrival rate of class-p messages to station i.

Fixed Priorities

1. Version I: As the protocol defined in [1] uses the reservation scheme of [3], the results from the later paper were used to obtain the expression for the steady-state average waiting-time of class-p messages at station i, in the former one:

$$\bar{W}_i^p = M + E\left[DL\right] - \frac{b_i^p}{2} + \left[\frac{\left(1+\rho_i^p\right)}{2} + \sum_{j=1}^{p-1}\sum_{g=1}^{M}\rho_g^j + \sum_{j=1}^{i-1}\rho_j^p\right]\frac{E\left[L^2\right]}{E\left[L\right]} - \frac{1}{2} \tag{1}$$

Where $\rho_i^p = \lambda_i^p b_i^p$ is the traffic in the terminal i due to the messages of class p, and $E\left[DL\right] = \lim_{n\to\infty} E\left[L_n^{DL}\right]$. This expression is still given as a function of E [L] and E [L^2], respectively, the first and second steady-state moments of the cycle length:

$$E\left(L\right) = \frac{M + E\left(DL\right)}{1-\rho} \tag{2}$$

Where

$$\rho = \sum_{p=1}^{P}\sum_{i=1}^{M}\rho_i^p < 1$$

and

$$\begin{aligned} E[L^2] &= \frac{1}{1-\sum_{p=1}^{P}\sum_{i=1}^{M}(\rho_i^p)^2}\Big\{M^2 + E[DL]^2 + 2ME[DL] \\ &+ \Big[2\rho(M+E[DL]) + \sum_{p=1}^{P}\sum_{i=1}^{M}\lambda_i^p b_{2,i}^p\Big]E[L] \\ &+ \Big[\sum_{p=1}^{P}\sum_{i=1}^{M}\sum_{\substack{j=1\\ j\neq i}}^{M}\rho_i^p\rho_j^p + \sum_{p=1}^{P}\sum_{\substack{q=1\\ q\neq p}}^{P}\sum_{i=1}^{M}\sum_{k=1}^{M}\rho_i^p\rho_k^q\Big]E^2[L]\Big\} \end{aligned} \tag{3}$$

2) Version II: The analysis for Version II follows in a direct manner noting that, the messages are transmitted in the same order as in Version I, with the classes of the messages exchanged for the numbers of the stations and vice-versa (see Section III). Therefore, the expression in the Version II is analogous to that in Version I, changing only the M by the P and the i for the p:

$$\overline{W}_i^p = M + E[DL] + [\frac{(1+\rho_i^p)}{2} + \sum_{j=1}^{i-1}\sum_{k=1}^{P}\rho_j^k + \sum_{j=1}^{p-1}\rho_j^p]\frac{E[L^2]}{E[L]} - \frac{1}{2}, \tag{4}$$

with E[L] and E[L2] given by equations (2) and (3), respectively.

V. RESULTS

An evaluate the level of differentiation obtained with the described schemes, we considered two distinct scenarios, where in each scenario there is a differentiated probability between four classes of traffic (P = 4), as shown in Table I.

Table I, Traffic Scenarios Used

Traffic classes	Scenario I	Scenario II
Class 1	25%	15%
Class 2	25%	20%
Class 3	25%	30%
Class 4	25%	35%

To simulate the presented models under balanced and unbalanced traffic conditions, we assume that:

1. Balanced case: there are 10 stations (M=10), each station shares with a traffic percentage (ρi = ρ/10), and each station contributes with its traffic class according to Table I.

2. Unbalanced case: similarly M=10, but 72% of the traffic from station "5" and the remaining 28% of the traffic from other stations (3% from each station), each station has traffic type as illustrated in Table I.

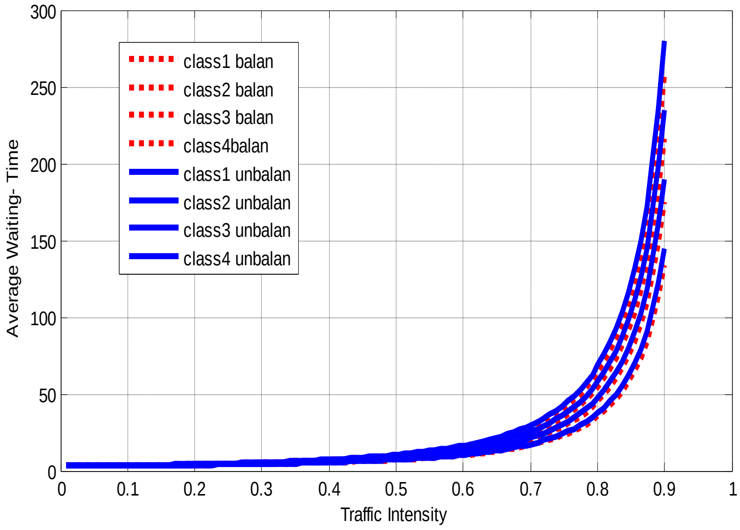
We assume that the number of packets in each message of class p in the station i is constant with average bip = 5 and b2,ip = 25, for each p = 1, 2, 3, 4; and i = 1, ..., 10. So, the average waiting-time for the class p is given by:

$$\overline{W}^{p} = \sum_{i=1}^{10} \frac{\lambda_i^p}{\lambda^p} \overline{W}_i^{p} \qquad (5)$$

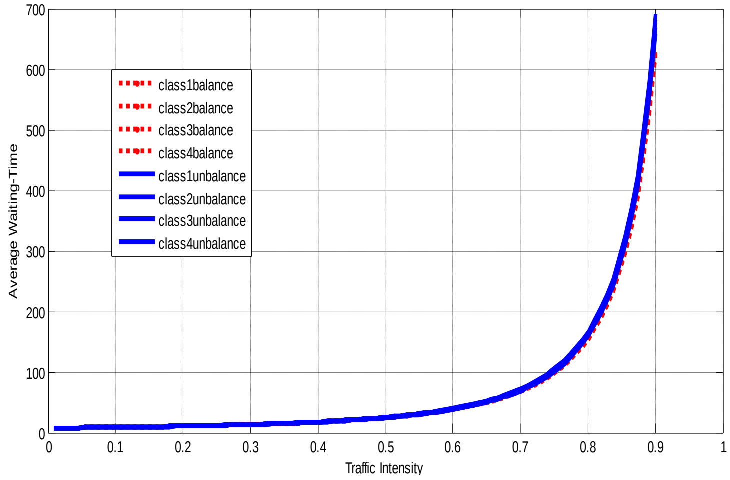
Where $\lambda_i^p = \rho_i^p / b_i^p$ and $\lambda^p = M * \lambda_i^p$

A. **Average Waiting-time vs. Traffic Intensity**

The performance of the model is measured for the average waiting-time per class. Fig. (7) and Fig. (8) illustrate the average waiting-time in the queue for each class of priorities related to the offered traffic in the channel using the TDD allocation schemes.

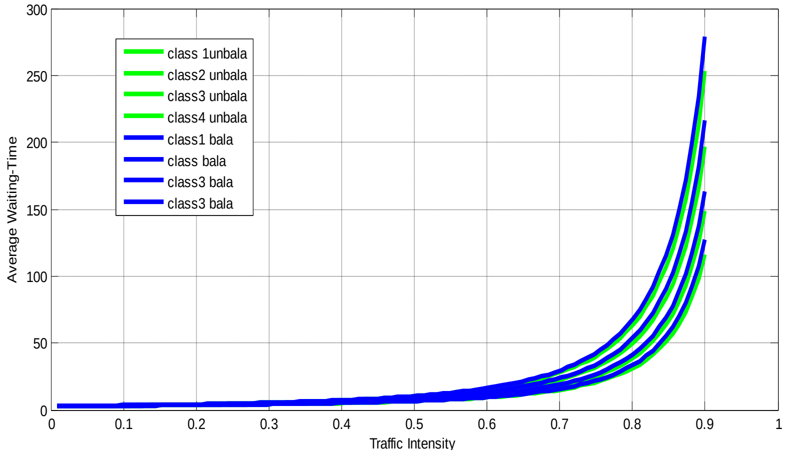


(a) Version I

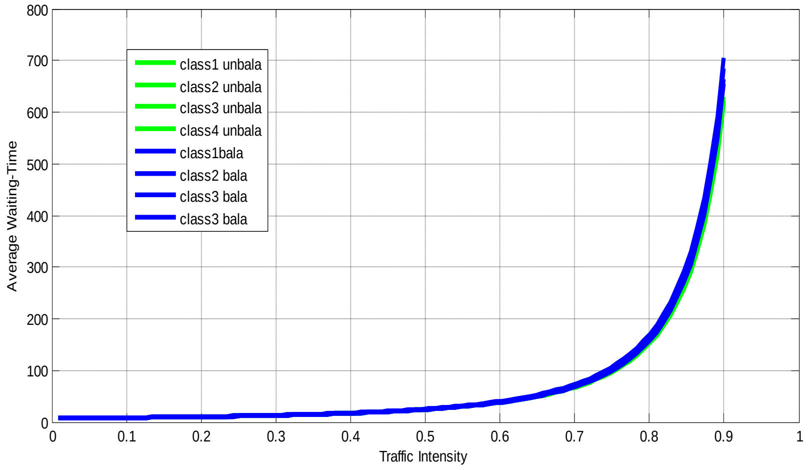


(b) Version II

Fig7. Average Waiting-Time vs. Traffic intensity in Scenario1 under Balance and Unbalance Case (a) Version I (b) Version II with M=10



(a) Version I



(b) Version II

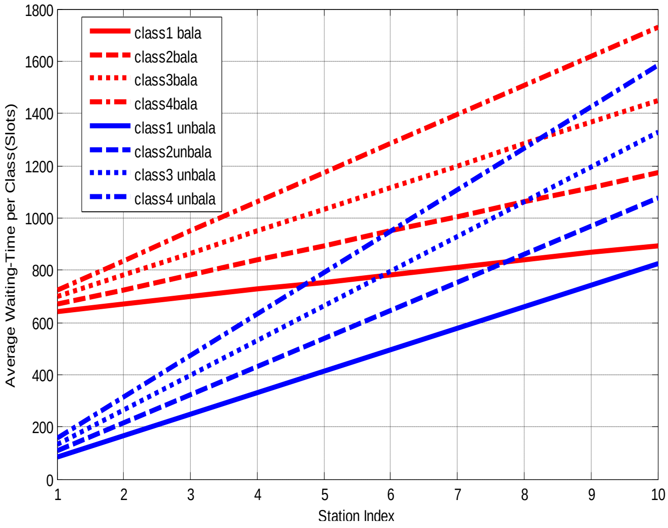
Fig8 .Average Waiting-Time vs. Traffic Intensity in Scenario-2 under Balance and Unbalance Case for (a) Version I (b) Vversion II with M=10

Both Figures that the average waiting-time of class-p message versus traffic intensity is completely equals for both balanced and unbalanced traffic conditions. This occurs because in these models, we deal with over all traffic intensity which equals to the sum of traffic intensities from all SSs. From fig (7) and fig (8) we note that the average waiting-time increases with the increase in traffic intensity, especially at heavy traffic condition. It can also notices that the differentiation between classes is clearly in Version I than Version II because in Version I, the priorities between classes prevail over the priorities between stations, while in Version II Where the priorities between the stations superpose. It observes that the waiting-time for the traffic of higher priority (class 1). For Version I in both scenarios, we observe that the waiting-time for each class depends on traffic intensity of this class and traffic intensities of all classes which have higher priority than this class

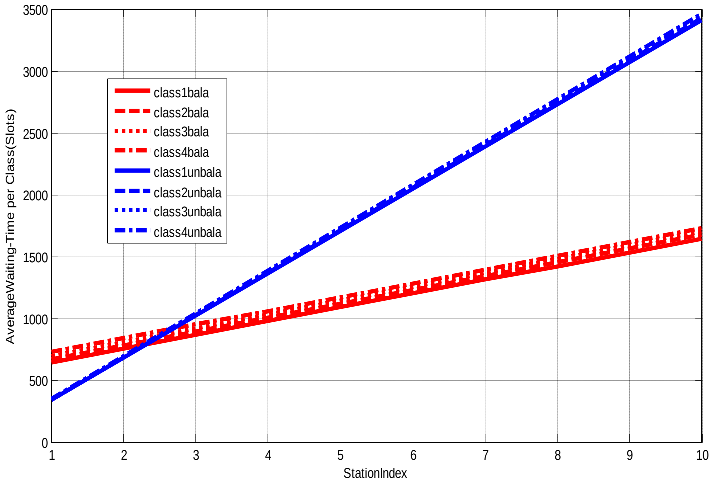
B. Average waiting- time versus station index

Fig. (9) and Fig. (10) Present the average waiting-time in the stations queue for traffic intensity (ρ= 0.9) for balanced and unbalanced traffic conditions. In this way, the average waiting-time in the queue for the station i is given by (6), where λi represents the message rate in the station-i.

$$\overline{W_i} = \sum_{p=1}^{4} \frac{\lambda_i^P}{\lambda_i} \overline{W_i}^P \qquad (6)$$

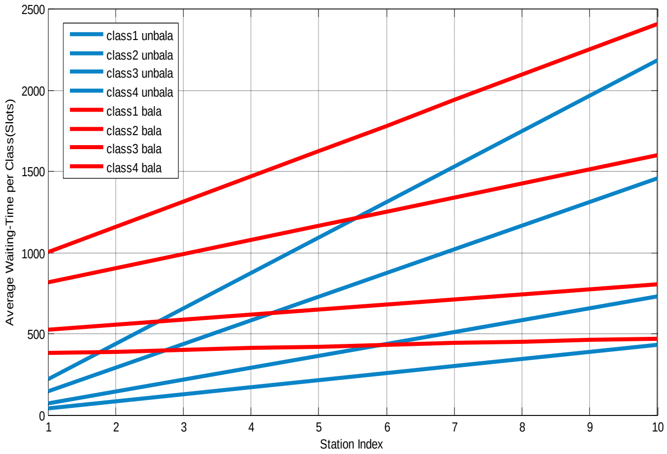


(a) Version I

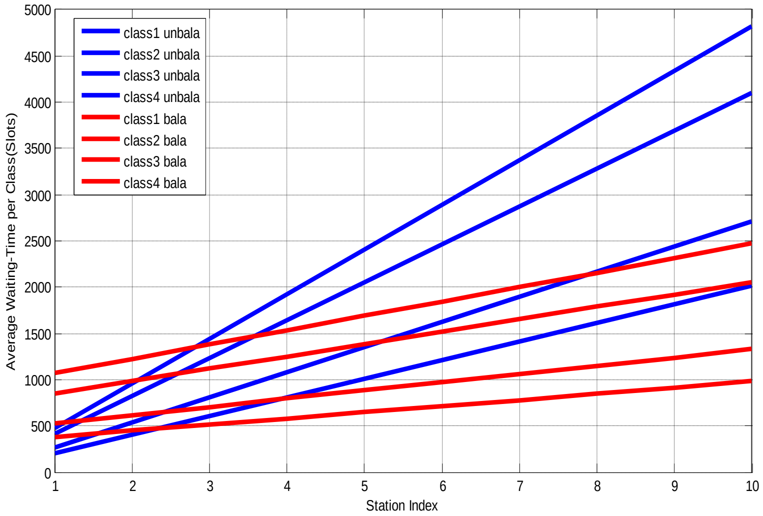


(b) Version II

Fig. 9. Average Waiting-Time vs. Station Index in Scenario-1 under Balanced and Unbalanced Cases (a) Version I. (b) Version II



(a) Version I



(b) Version II

Fig. 10. Average Waiting-Time vs. Station Index in Scenario-2 under Balanced and Unbalanced Cases (a) Version I. (b) Version II

Form Figures (9) and (10) it can be observe that for balanced and unbalance traffic conditions, the average waiting-time increases uniformly with the increase in station index. But the increases in waiting-time with the increases in station index are clearly in unbalance case than balance case.

VI. CONCLOSTION

In this paper, a modified MAC reservation scheme is proposed for BWA systems which incorporate traffic scheduling functions with message-or station-based priorities Moreover, an analytical model is devised for the mean message waiting-time for the different traffic scenarios, using TDD allocation scheme, and assuming Poisson arrivals of messages and general distributions for message lengths. According to the results exposed in this work , we can conclude that the maximum difference in waiting-time between stations for Version I is smaller than that for Version II , for the balance and unbalance traffic conditions, the average waiting-time of class-p versus traffic intensity is completely equals. Systematic increase in waiting-time is observed as the station index increase. This obvious clearly in unbalance traffic case than balance traffic case.

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