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R.M. Santos, J. Santos *, J. Orozco, M. Zambon

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Real-time multimedia standards in DQDB

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Abstract

In the present work, the necessary and sufficient conditions for the real-time schedulability of Dual Queue Dual Bus (DQDB) networks are formally proved, strictly adhering to the letter of the standard as it stands today. With those results, the quality of the standardized multimedia applications that a given DQDB network can carry is analysed. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Real-time; Multimedia standards; DQDB

1. Introduction

The suitability of the Dual Queue Dual Bus (DQDB) (ISO/IEC 8802-6 or IEEE 802.6) standard to operate satisfying real-time constraints has been deemed questionable [11]. The purpose of this paper is to analyse its performance as a subnetwork of a Metropolitan Area Network (MAN) and to determine up to what quality of multimedia applications it can carry. Since DQDB will probably be heavily used in the transmission of videotelephony and teleconferencing, the importance of the subject is obvious.

2. Scheduling policies and methods

In real-time communications systems, messages are generated periodically at each station. In order to solve in a deterministic way the problem of assigning the use of the transmission medium when two or more stations contend for it, linear ordering relations induced by scheduling policies, also called priority disciplines, are used. Effective policies to be applied to hard real-time systems boil down to Fair Round Robin, Rate Monotonic (RM) and Earlier Deadline First. RM is a *de-facto* standard [10] in which messages are ordered by increasing periods. In its present form, the DQDB standard is unable to implement any of those policies. It incorporates, instead, priority mechanisms for an *ad-hoc* discipline.

The Empty-Slots Method, presented in Ref. [10] to solve the scheduling problem of real-time LANs, will be used to test the schedulability of the DQDBs networks. Time is considered to be slotted. Slots are denoted t and numbered $1, 2, \ldots$ The duration of one slot, called *slot-time*, is taken as unit of time. A set of m stations, $S(m)$, transmitting unitary (one slot) real-time messages is completely specified by the set of periods T_i, $1 \leqslant i \leqslant m$. To meet the time-constraint, each message must be transmitted within its period.

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PII: S 1 3 8 3 - 7 6 2 1 (9 9) 0 0 0 1 9 - 3

If the RM discipline is used and priority ordered stations are designated $1, 2, \ldots, m$, it is formally proved in Ref. [11] that $S(m)$ is schedulable iff for $i = 2, 3, \ldots, m$,

$$\sum_{h=1}^{i-1} \frac{1}{T_h} < 1 \quad \text{and} \quad T_i \geqslant \text{least } t \,|\, t = 1 + \sum_{j=1}^{i-1} \left\lceil \frac{t}{T_j} \right\rceil$$

hold. The intuitive reasons behind the mathematical expressions are simple: The first one says that $S(i-1)$ leaves at least one empty slot to accommodate the message from station_i. The second one establishes that T_i must be larger than or equal to the first slot left empty by $S(i-1)$, in order to accommodate all the messages of higher priority $\sum_{j=1}^{i-1} \lceil (t/(T_j)) \rceil$) and still have one slot free to transmit station_i's message.

3. A summary of the DQDB medium access protocol

The DQDBs high-speed shared medium access protocol is used over a dual counter-flowing unidirectional optic fibre bus subnetwork [4] (Fig. 1). It covers the physical layer and the medium access control sublayer of the ISO-OSI model [13]. In each bus, denoted A and B, information flows in opposite directions, at 155.520 Mb/s. Messages of a station are transmitted on one bus (*forward*) to downstream stations and reservations on the other bus (*reverse*). In what follows, the terms up and downstream will be referred to forward bus A. The dual case is obviously valid.

Data are transmitted in fixed length *slots*, generated by the stations at the head of each bus. Each slot is 53 bytes long. The first one is used for control and the other 52, of which 48 are payload, constitute what is called a *segment*. Reservations are made by setting a bit in the control byte as slots pass on the reverse bus. In this way, the station places itself in the distributed queue by making its reservation known to upstream stations.

When the station has a segment to be transmitted, it puts the seen number of downstream reservations in a regressive counter decremented with each empty slot passing on the forward bus. When it reaches value zero, the segment can be transmitted by placing it in the first empty slot passing in front of the station. No segment can be queued before transmitting the previous one but, on the other hand, access is not inhibited if the value of the counter is zero although the request bit associated with the segment has not yet been written to the reverse bus ([4], p. 44). Although the probability is very low, in the worst case this situation may happen in all the previous $(i-1)$ upstream stations and therefore station_i will see its position in the queue postponed $(i-1)$ slots-times or, what is equivalent, will suffer $(i-1)$ priority inversions. As it is pointed out in the standard itself, *"priority should not be relied upon for all subnetwork distance, speed and loading conditions"* ([4], p. 49).

4. DQDB real-time schedulability

Sha et al. [12] proposed the DQDB protocol able to implement RM preemptive scheduling. However, major modifications to the standard

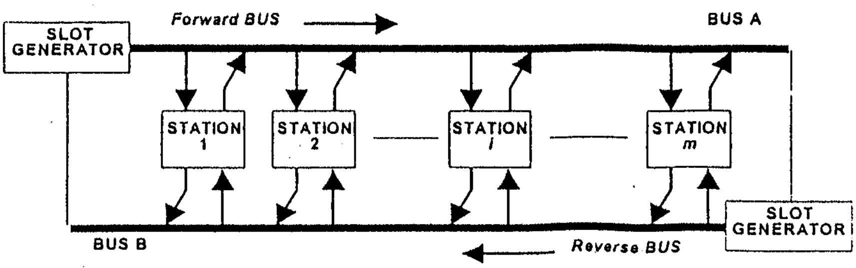

Fig. 1. The DQDB structure.

are necessary. Bisdikian and Tantawy [1], Leu and Du [7], Han et al. [3], Sharon [12] and Saha et al. [9] have also proposed improvements to the standard but they require substantial modifications too. On an opposite approach, we may ask what the capabilities of the standard are and what can be done to extract the best of it strictly in the context of its letter as it stands today.

The slot-time is the time the station needs to put the 53 bytes of a slot in the bus. It is 53 (bytes)* 8 (bits/byte)/155.520 (Mb/s) = 2.73 μs. A slot-distance will be the distance traversed by the signals in one slot-time. If the propagation speed is accepted to be two thirds of the speed of light in vacuum, one slot-distance equals $2/3 * 3 \times 10^8$ (m/s) $* 2.73 \times 10^{-6}$ (s) = 546 m. In this way, not only delays associated to transmission but also to propagation can be measured in slots.

Let us now find the maximum delay, R_i, that a slot may suffer from the instant at which the segment is queued and the instant at which its last bit is transmitted. Transmission takes one slot and d_i denotes the distance from station_i to the bus A's slots generator end.

Lemma.

$$R_i = (i - 1) + 2\, d_i + 1. \qquad (1)$$

Proof. The first term corresponds to priority inversions as explained before. The second term takes into account the propagation of the reservation bit from station_i to the forward bus generator end and the propagation back of the empty-slot destined to carry the segment. The third term corresponds to the transmission delay (one slot). ☐

The lemma gives an upper bound to the delay. Since it is a function of the position of the station in the buses, it will be different for each station. The worst case of load takes place when each station of the network queues one segment whenever possible, which is immediately after transmitting the previous one. With that in mind, we may go now to the following theorem.

Theorem. *The DQDB network transmitting a continuous flow of slots at each station is schedulable iff*

$$\forall i \in \{1, 2, \ldots, m-1\} \qquad T_i \geqslant \text{least } t | t = R_i + \sum_{j=i+1}^{m} \left\lceil \frac{t}{T_j} \right\rceil \qquad (2)$$

holds.

Proof. The first term is a consequence of the lemma. The second term gives the number of slots necessary to accommodate the segments produced by the downstream stations in the interval $[1, t]$.

Since multimedia applications are often characterized by the net bandwidth necessary to transmit them, it is convenient to present the available payload bandwidth, *ABW*, at each node.

As an example, Fig. 2 shows the available bandwidths for three DQDB networks having 10, 50 and 100 stations, equally spaced 10, 2 and 1 slot, respectively, along the buses. Their lengths are 90, 98 and 99 slots-distance or 49.1, 53.5 and 54.0 km, respectively. Calculations start with the last station and proceed recursively backwards towards the first one, applying (1) and (2). As the worst case, the least *ABW*, corresponding to the last station, is taken as the *ABW* of every node. Obviously, the potential real-time use of the network will be different for each station. ☐

5. Multimedia applications

The necessary bandwidth for a multimedia application depends on the sampling period and the amount of bytes to be transmitted at each sampling. The most widely used international standards for video compression are H261 and MPEG. The first one was specifically designed for videoconferencing and visual-telephony while MPEG has a wider scope of applications.

H261 was developed by a specialists group appointed by the International Telegraph and Telephone Consultative Committee. The standard was approved in 1990, providing audiovisual services at p * 64 Kb/s, ($p = 1, 2, \ldots, 30$) [8], at bandwidths ranging from 64 Kb/s to 1.92 Mb/s. H261 supports two image resolutions, the Common Intermediate

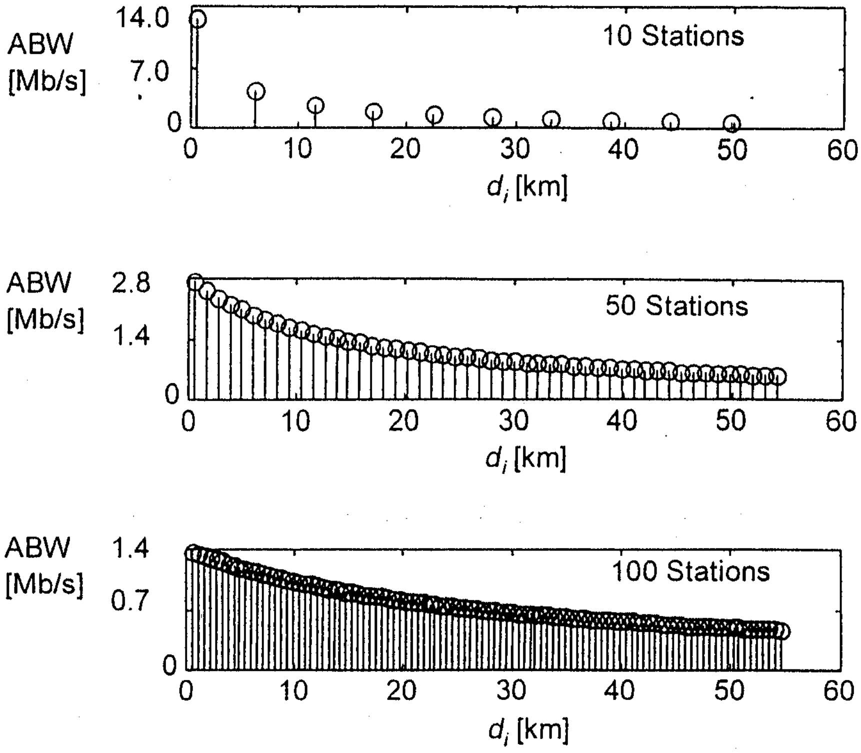

Fig. 2. Stations' *ABW*.

Format (CIF) and the Quarter-CIF (QCIF). The first one is 288 * 352 pixels while the second one is 144 * 176 pixels. Both can be transmitted at various frames/s rates. Compressions of near 50:1 are used. They lead, for instance, to the following necessary bandwidths: QCIF, 15 frames/s, $p = 1$, 64 Kb/s; CIF, 10 frames/s, $p = 1$, 64 Kb/s; CIF, 15 frames/s, $p = 5$, 320 Kb/s, all within the DQDB capabilities.

MPEG is the acronym of the Moving Picture Experts Group of the International Standards Organization. There are four MPEG standards, designated I to IV. The first two have higher quality than H261 but the price to pay is 1.2 and 2 Mb/s as lower bounds on bandwidth, respectively [6]. MPEG III was dropped in favour of MPEG II [2]. MPEG IV is aimed at low bandwidth or low storage capacities. It will become an international standard in January 1999 under the formal designation ISO 14496 [5]. It is founded on model-based image coding schemes and aimed at up to 64 Kb/s, making it specially attractive for DQDB transmissions.

6. Conclusions

As can be seen, DQDB is able to support communications complying with H261 and MPEG IV, both very important audio/video multimedia standards, with applications in video-telephone, video conferencing, video mail and electronic publishing.

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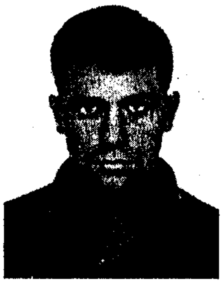

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