Fair Uplink Scheduling for rtPS traffic in IEEE 802.16 Broadband Wireless Systems

Zeeshan Ahmed, Salima Hamma

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Zeeshan Ahmed — Salima Hamma

LUNAM Université, Université de Nantes
IRCCyN, CNRS UMR 6597, Polytech′ Nantes
rue Christian Pauc, BP 50609 - 44306 Nantes Cedex 3, France
{zeeshan.ahmed,salima.hamma}@univ-nantes.fr

ABSTRACT. *IEEE 802.16 standard provides a revolutionary air interface that enables very high data rates over large distances. It is also one of the leading candidates to become the official standard of next generation of cellular networks. It incorporates a Quality of Service (QoS) framework to ensure satisfactory transmission of different classes of traffic. However, the actual implementation of QoS mechanisms is not defined in the standard and left out for vendors. One of the five different classes of services supported by the standard is real-time polling service (rtPS). Scheduling rtPS traffic is the trickiest because of its bursty nature and tight delay constraints. In this article, we provide an algorithm for fair scheduling of rtPS traffic in uplink direction. The proposed algorithm is simple and efficient and therefore it is suitable for high speed data networks. Simulation results are provided to show that the algorithm is fair and efficient.*

RÉSUMÉ. *Le standard IEEE 802.16 offre une interface radio révolutionnaire qui permet des débits très élevés sur des grandes distances. Il est également l'un des principaux candidats pour devenir le standard officiel de la prochaine génération de réseaux mobiles. Il intègre un framework de qualité de service (QoS) pour assurer une transmission satisfaisante des différentes classes de trafic. Néanmoins, la mise en œuvre effective des mécanismes de QoS n'est pas définie dans la norme IEEE 802.16 et laissé à la libre appréciation des construteurs. L'une des cinq classes différentes de services pris en charge par le standard est le real-time polling service (rtPS). La planification du trafic rtPS est la plus délicate en raison de sa nature sporadique et des contraintes de délai serré. Dans cet article, nous proposons un algorithme pour la planification équitable de rtPS pour la liaison montante. L'algorithme proposé est simple et efficace et il est donc approprié pour le cas des réseaux à grande vitesse. Les résultats de simulation apportés dans ce papier montrent que l'algorithme répond au problème posé tout en étant efficace.*

KEY WORDS: *IEEE 802.16, WiMAX, QoS, rtPS, scheduling*

MOTS-CLÉS : *IEEE 802.16, WiMAX, QoS, rtPS, ordonnancement*

1. Introduction

The advancements in the Internet and mobile communication has resulted in a tremendous growth in the number of users who use these services. There is also a continuous trend of increased usage of multimedia services, such as IPTv, video conferencing, VoIP etc. These applications require huge resources and put enormous burden on network infrastructure. In fact, current cellular networks would not be able to cope up with the increasing demand within next few years [WiM 08]. Therefore, there is a need of faster and more reliable networks to support the future applications. Furthermore, to maintain an acceptable level of service, a network must also be able treat applications according to their priorities. In this regard IEEE 802.16 [IEE 06] (WiMAX) is an ideal choice. It offers very high data rates over large distances. Moreover, it incorporates a well-defined QoS framework. It supports five classes of services: (i) Unsolicited Grant Service (UGS) (ii) Extended Real-Time Polling Service (ertPS) (iii) Real-Time Polling Service (rtPS) (iv) Non-Real-Time Polling Service (nrtPS) (v) Best Effort (BE) Service.

Scheduling is an essential element of any QoS architecture. The complex task of scheduling is performed by three schedulers in WiMAX i.e. Base Station (BS) downlink scheduler, BS uplink scheduler and Subscriber Station (SS) scheduler. The functions of these schedulers are defined, however the details are not defined in the standard and left out for vendors [TAL 08]. The most complex task is performed by the BS uplink scheduler as it does not have complete view of queues that are maintained at SSs. Furthermore, scheduling rtPS traffic is the trickiest because of its bursty nature and tight delay constraints. The article provides an algorithm for the BS uplink scheduler to fairly schedule rtPS traffic.

2. Methodology

Firstly, we present the terminology that is important to understand the rest of the article.

(i) r_i^{min} : minimum reserved traffic rate for connection (MRTR) i (ii) r_i^{max} : maximum sustained traffic rate for connection i (iii) d_i : delay limit for connection i (number of uplink frames) (iv) bw_i: bandwidth requested by connection i in current frame (v) n : number of rtPS connections admitted (vi) d_{max} : $max(d_i)$, where $i = 1, 2, ...n$ (vii) $bwTable$: an $n \times d_{max}$ table (viii) f : current uplink frame (ix) r_f : unused bandwidth in frame f (x) SR_i : service ratio for connection i (xi) SR : total service ratio (xii) r^a : total uplink bandwidth available

A new rtPS connection k is admitted by BS only if $r_k^{min} \leq r^a$. It is assumed that a traffic conditioner is present at the SS that keeps the bandwidth demand always below r_k^{max}. For each uplink frame the BS allocates bandwidth to connections in increasing order of d_i, i.e. priority is given to the connection with the tightest delay constraint. In order to guarantee fairness among rtPS flows *Service Ratio* is computed for each flow, as shown in Eq. 1. So, a session i is only allow to transmit data if $SR_i \leq SR$. The idea is to guarantee MRTR for each session, while fairly distributing the available bandwidth among active rtPS flows.

The scheduler keeps an $n \times d_{max}$ table, where an entry in j_{th} row and k_{th} column signifies the bandwidth allocated to connection j in frame $f + k$. The table is used by the scheduler to generate UL-MAP. In each round a connection i is only allowed to transmit data if $SR_i \leq SR$. Unlike other

Algorithm 1 The proposed algorithm

```
for i = 1, 2, ...n do
   if SR_i ≤ SR and r_f ≥ bw_i then
      set bwTable[i][0] = bw_i
   else if r_{d_i} ≥ bw_i then
      set bwTable[i][d_i] = bw_i
   end if
end for
if r_f > 0 then
   reschedule r_f from f + 1 to f
end if
generate UL-MAP
```

algorithms, a SS needs not to send the sum of backlog as bandwidth request. A SS can simply send the actual new bandwidth demand generated to the BS. This is both simple and efficient. The scheduler tries to allocate bandwidth in the current frame, however if enough space is not available then it allocates the remaining bandwidth in frame $f + d_i$.

$$SR_i = \frac{\sum_{t=1}^{f-1} BW\ allocated\ to\ conn\ i\ in\ frame\ t}{\sum_{t=1}^{f-1} BW\ requested\ by\ conn\ i\ in\ frame\ t} \qquad i = 1, 2, ..., n \qquad [1]$$

$$SR = \frac{\sum_{t=1}^{f-1} total\ uplink\ BW\ available\ in\ frame\ t}{\sum_{t=1}^{f-1} \sum_{i=1}^{n} BW\ requested\ by\ conn\ i\ in\ frame\ t} \qquad [2]$$

3. Simulation Results

The performance of the proposed algorithm is evaluated by developing a simulation model. The goal is to accurately determine the bandwidth allocation to each SS. It is assumed that: (1) Packets arrive at start of a frame. (2) There is only rtPS traffic (3) All connections are already admitted. (4) Total uplink bandwidth = 10 Mbps (5) Four rtPS connections with parameter as shown in Table 1. These parameters imply a very heavy load on system as $SR \simeq 50\%$

Connection	r^{min} (kbps)	r^{max} (kbps)	Max Delay (frames)
A	4000	9000	2
B	1000	3000	3
C	2000	4000	3
D	3000	5000	4

Table 1. *Input traffic parameters*

Figure 1 shows the service ratio for each rtPS connection as well as total service ratio SR. It is obvious that service ratios of all rtPS connections adapt and follow SR. Even though the available bandwidth could only provide minimum guaranteed service to each rtPS, the proposed algorithm performed very well and dynamically allocate bandwidth to ensure fairness. In fact, SR is the best a connection can get and all the connections seem to follow SR rather well. Thus it proves that the algorithm is able to fairly allocate maximum possible bandwidth to each admitted rtPS connection.

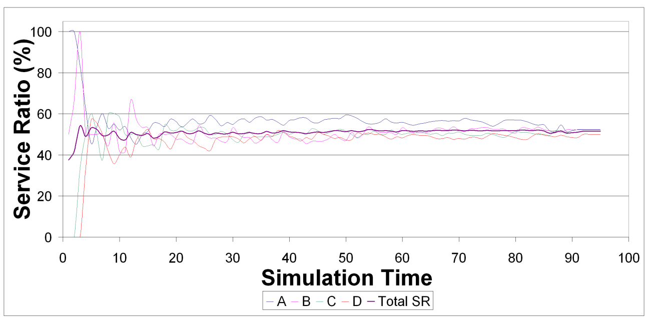

Figure 1. *Service ratio for rtPS connections*

4. Conclusion

In this article an algorithm is provided for IEEE 802.16 networks that provides fair uplink scheduling of rtPS traffic. The scheduler is fast, efficient and easy to implement. The simulation results prove that the algorithm is able to fairly allocate maximum possible bandwidth among all admitted rtPS connections.

5. References

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