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A multi-model reference control approach for bandwidth-on-demand protocols in satellite networks

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Abstract

This paper presents a multi-model reference control (MMRC) approach for queue-based bandwidth-on-demand (BoD) procedures in geostationary satellite networks. BoD access protocols address the problem of guaranteeing a high exploitation of the valuable satellite bandwidth while offering acceptable end-to-end delays to the traffic accessing the network. In queue-based protocols, the controller objective is to drive the buffer queue length to a certain target queue length; in the proposed scheme, model references (MRs) are used to address the problem of adapting the target queue length to the statistical characteristics of the traffic. The reference queue length is computed as a weighted sum of the outputs of the different MRs; the weights are computed on-line by evaluating the network utilization achieved by each MR, in response to the actual traffic feeding the system. Moreover, the target network utilization is dynamically varied based on the estimated network load. The BoD performances are evaluated via simulations. The work underlying this paper is based on the results of the GEOCAST,[1] SATIP6[2] and SATSIX[3] projects, financed by European Union.

Keywords: Model reference control; Smith's principle; Satellite networks; Bandwidth-on-demand

1. Introduction

Next generation geostationary satellite systems will support multimedia traffic, which is characterized by high burstiness (i.e., high ratio between peak and average bit rates); thus, considering that wireless resources are expensive, the problem of designing an efficient access procedure is crucial.

The work presented in this paper is based on the work carried out by the University of Rome "La Sapienza" within the GEOCAST, SATIP6 and SATSIX projects belonging to the 5th and 6th framework programmes of the European Union. The scenario considered by these projects, depicted in Fig. 1, consists of a digital video broadcasting-return channel via satellite (DVB-RCS) (ETSI, 2003, 2005) geostationary satellite network with on-board switching capabilities; satellite terminals (STs) provide local area networks (LAN) with the access to the network; gateways connect the satellite network to the core network (i.e., to the Internet); satellite network resources are managed by a network control centre (NCC), located on earth.

STs are boundary devices between satellite and terrestrial links and play an important role in access to satellite resources and in quality of service (QoS) provision by implementing two fundamental functions:

(1) *Traffic control*, whose aim is to differentiate the IP flows to support different classes of services (e.g.,

Abbreviations: BoD, bandwidth-on-demand; DVB, digital video broadcasting; DVB-RCS, DVB-return channel via satellite; FCA, free capacity assignments; HP, high priority; IETF, Internet engineering task force; IP, Internet protocol; LAN, local area network; LP, low priority; MR, model reference; MRC, model reference control; MMRC, multi model reference control; NCC, network control centre; QoS, quality of service; ST, satellite terminal.

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[1]GEOCAST (multicast over geostationary EHF satellites) project (contract IST-1999-11754): http://www.geocast-satellite.com/.

[2]SATIP6 (satellite broadband multimedia system for IPv6) project (contract IST-2001-34344): http://satip6.tilab.com/.

[3]SATSIX (satellite-based communications systems within IPv6 networks) project (contract IST-2006-26950): http://www.ist-satsix.org/.

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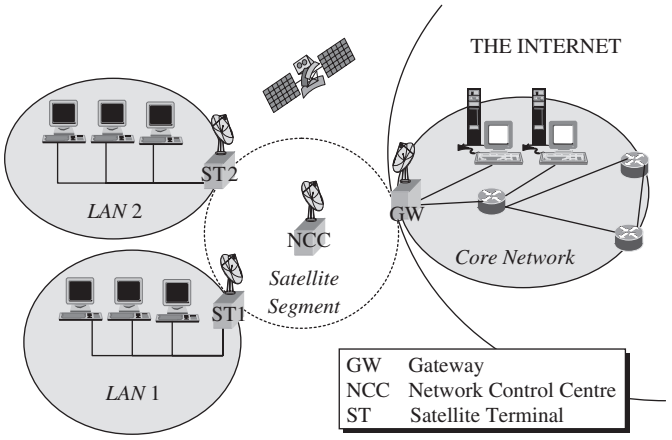

Fig. 1. Geostationary satellite network.

DiffServ classes, see Blake et al., 1998). *Traffic control* performs classification, regulation and scheduling of IP traffic to transmit in the satellite segment; in this way, STs can decide which IP flow to serve via the available uplink bandwidth (Inzerilli, Paone, Pietrabissa, & Tarquini, 2004).

(2) *Access control*, whose aim is to regulate the access to the uplink bandwidth contended by the STs in order to assure fair bandwidth allocation and efficient link bandwidth exploitation.

As analysed by Karaliopoulos, Tafazolli, and Evans, 2004, and by Delli Priscoli, and Pietrabissa, 2004a, the two procedures can be developed separately. In this paper, *traffic control* procedures are not examined; for the interworking between the *access* and *traffic control* procedures, the interested readers are referred to Pietrabissa et al. (2005).

Access control objective is to provide STs with uplink bandwidth. Data packets of traffic sources are forwarded to the STs; since the STs share common satellite uplink resources, to prevent collisions between packets transmitted by different STs, they have to ask the NCC, for the reservation of a certain amount of bandwidth. The NCC grants the bandwidth by means of two main approaches:

(1) *Static bandwidth assignment*: at connection setup, the NCC assigns a certain amount of bandwidth to the ST. Since this pre-assigned bandwidth is always available to the ST, low delays can be granted; the drawback is that, since bandwidth assignments are unrelated to the actual offered traffic, the satellite links are likely to be under-utilized. This approach is advantageous for traffic with limited bit rate variations and for connections having stringent transfer delay requirements (e.g., real-time traffic such as voice or video).

(2) *Dynamic bandwidth assignment*: the NCC assigns the bandwidth to a certain ST based on the bandwidth requested by the ST, computed via the bandwidth-on-demand (BoD) mechanism. Since the STs send bandwidth requests and then wait for the bandwidth assignments, the latency of this approach is affected by the propagation delay of satellite links; the advantage is that assignments track the actual traffic dynamic achieving efficient bandwidth exploitation.

High priority (HP) service classes with bandwidth and delay guarantees require static assignments, due to the excessive latency of the BoD request–assignment cycle. Low priority (LP) service classes should be supported via the dynamic approach. This paper considers the HP traffic handled with static bandwidth assignments as background traffic and focuses on the BoD mechanisms adopted for the LP traffic handled with dynamic bandwidth assignments.

1.1. Objectives of the BoD scheme

BoD procedures define the rules by which the STs request the transmission bandwidth to the NCC (Delli Priscoli & Pietrabissa, 2002); once the NCC receives the *bandwidth requests*, it computes and transmits the *bandwidth allocation* on the basis of: (i) the received requests and (ii) the current bandwidth availability. The BoD procedure addresses the trade-off between two contrasting objectives:

(a) STs should be capable of utilizing the whole requested bandwidth (*full link utilization*). This means that proper amount of packets should be accumulated in the ST buffer: in fact, if the ST has no packets in the buffer queue when the bandwidth allocation is received, the unused allocated bandwidth is wasted.

(b) The queue length in the ST buffer should be as small as possible, in order to reduce the queuing delay. The former objective has priority when the network load is high, i.e., when the bandwidth is scarce, whereas the latter has priority when the network load is low.

This trade-off is partially addressed if the NCC assigns also the leftover bandwidth not requested by the STs, by means of the so-called free capacity assignments (FCA): in fact, FCAs, which are abundant when the network load is low, can be used by the STs to reduce the queue lengths, but can also be wasted if the STs have empty buffers. The problem with FCAs is that the actual requirement of each STs is not known by the NCC: as analysed in this paper, ST requirements heavily depend on the traffic statistic characteristics. Thus, objective C of the BoD scheme is to dynamically adapt the request policy to the network load: if the network is congested, the STs aim at the full link utilization; as the load decreases, the STs should increase their bandwidth requests based on traffic measurements.

1.2. Related work and paper outline

The debate on satellite BoD algorithms is becoming a central point even in the framework of standardization