Study of the CAC mechanisms for Telecommunications Systems with adaptive links according to propagation conditions

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Abstract— This paper presents the framework and the activities of a PhD research work in progress supported by Alcatel Alénia Space in collaboration with TéSA and SUPAERO. It deals with Connection Admission Control (CAC) for Telecommunications Systems with adaptive links according to propagation conditions. Indeed, in high frequency bands communications, deep fadings may occur because of atmospheric propagation losses. The mitigation techniques used to counteract fades impacts the system capacity, therefore the CAC mechanism. The CAC which only uses current capacity information may lead to intolerable dropping of admitted connection, and thus breaches the QoS guarantees made upon connection acceptance. New CAC mechanisms shall be studied to take into account the capacity variation and the mitigation techniques (IFMT) developed to compensate the attenuation in Ka and above frequency range.

I. CONTEXT

Since the implementation of the first multimedia access systems by satellite, mainly based on DVB-RCS (Digital Video Broadcasting with Return Channel by Satellite), industries have been trying to improve the satellite system capacity and to reduce the cost of the Satellite Terminals (ST). The propositions made in the DVB-S2 (Digital Video Broadcasting Second generation) and DVB-RCS standardisation groups are linked to the use of Interference and Fame Mitigation Techniques (IFMT), in particular Adaptive Coding and Modulation (ACM) and Dynamic Rate Reduction (DRR). Thus, Gateways and Satellite Terminals, supporting « adaptive physical layers » and IFMT on forward and return links, should be developed. Although that development enables to reduce the transmission power on the return link - therefore the satellite terminals cost - , it also implies a reduction of the transmission channel capacity. This fact causes some difficulties to define a resource management and assignment protocol as the capacity varies when IFMT techniques are used.

II. EXISTING WORKS

Some earlier works conducted by Alcatel Alénia Space, TéSA and ONERA ([SAGAM] [ESA 4135]) have led to the progress on:

- the physical layer: IFMT implementation with power control.
- the multiple access: impact on Demand Assignment Multiple Access (DAMA), the resource management for the uplink, and on the multiplexing protocol when DVB-S2 is used on the Forward Link.

But few studies have been made on the impact of the variable capacity, involved by the mitigation techniques, on the Connection Admission Control (CAC), procedure which decides whether a connection can be admitted, based on the QoS requested and the resources available. In the thesis [PECH], the interactions between IFMT implementation on the physical layer (in Ka-band) and the resource management on the link layer (DAMA)[1] have been studied. The hypothesis of that work was that of a simple CAC function based on a « effective bandwidth concept » - depending on the traffic parameters, the equivalent rate for a user's session or application is calculated. Then the CAC checks if that rate can be achieved within the available rate of the system; and if so, the amount of the rate is reduced from the total amount of available rate.

III. REFERENCE SYSTEMS

A. Objectives

In the previous scenarii, the system capacity is considered by the CAC function as the available physical rate at an accurate moment. The new scenario is a CAC function which takes into account a historic knowledge of the system total rate and its possible evolution: the CAC function knows the way the capacity evolves, in a more or less long term, and then it is capable of anticipating the future state of the capacity. This leads to accept a Terminal or a session connection only if the CAC function supposes the required capacity to be available for a time long enough. Thus, CAC functions must deal with channel prediction and the intrinsic attributes of a variable capacity. This kind of CAC, really interesting for adaptive systems (which have a capacity that varies according to the FMT used) is the one considered in the present paper. The study takes into account the capacity variation due to IFMT, both on Return and Forward links.

B. Reference Network Architecture

The network reference model is that used for access topology (star architecture) with a transparent payload in Ka-band.

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[1]DAMA function is shared among a centralised DAMA controller, located in the gateway/NCC, and DAMA agents localised in the STs. Both are responsible for allocating dynamically the MF-TDMA slots to the ST

DVB-S2 is used on the forward link (from Gateway to Satellite Terminals) and DVB-RCS on the return link (from Satellite Terminals to Gateway). The network is based on end-to-end IP (Internet Protocol). On the satellite links, IP is encapsulated in MPE (Multi-Protocol Encapsulation) on the forward link and ATM (Asynchronous Transfer Mode) on the return link.

IV. STATE OF THE ART

A. IFMT techniques

1) description: Multimedia satellite systems operating at high frequency bands (Ka band and above) suffer a lot from attenuations caused by rain, tropospheric scintillations, Gaussian noise (thermal and system internal interferences) [CAST]. Those atmospheric losses limit the satellite communication link availability, therefore the system performances. The approach followed by earlier communication systems is the allocation of fixed TDM downlink stream bit rate and power margin computed according to the required link availability when the channel quality is poor. Thus, these systems, effectively designed for the worst case channel conditions, result in insufficient utilization of the full channel capacity. Adapting to the signal fading allows the channel to be used more efficiently since the power and the rate can be allocated to take advantage of favourable conditions [GOLD]. IFMT are methods that tackle the atmospheric propagation losses and permit link adaptation. The growing demand for spectrally efficiency communication in current multimedia systems revives the interest in adaptive techniques. The basic idea behind adaptive transmission (IFMT) is to maintain a constant Eb/No by varying the transmitted power, symbol transmission rate, constellation size, coding rate/scheme, space diversity, or any combination of these parameters [GOLD]. Thus, without sacrificing bit error rate, these schemes provide high average spectral efficiency by transmitting at high speeds under favourable channels conditions and, reducing throughput as the channel degrades.

2) IFMT and Channel capacity estimation: CAC function policy is to accept or reject a connection request according to the amount of capacity needed for the arriving connection and the total amount of available rate; channel capacity estimation is so a major issue. Besides, adaptive transmission requires accurate channel estimates at the receiver and a reliable feedback path between the receiver and the IFMT controller in charge of adapting the transmitting flow. Channel capacity estimation is needed in satellite multimedia systems to reach the best spectral efficiency. For that purpose, the best IFMT mode must be found when attenuation occurs on the link. Many studies have dealt with that topic. As an example [GOLD] proposes a variable-rate and variable-power MQAM modulation scheme for high-speed data transmission over fading channels; Similarly,[GAUD] tackles the problem of finding an optimal physical layer (coding rate, modulation order, spreading factor, frequency and polarization reuse factors) able to efficiently support packet type of traffic and to adapt to the varying propagation channel conditions and location dependent signal to interference plus noise ratio. [SHIO] gives a capacity estimation methodology.
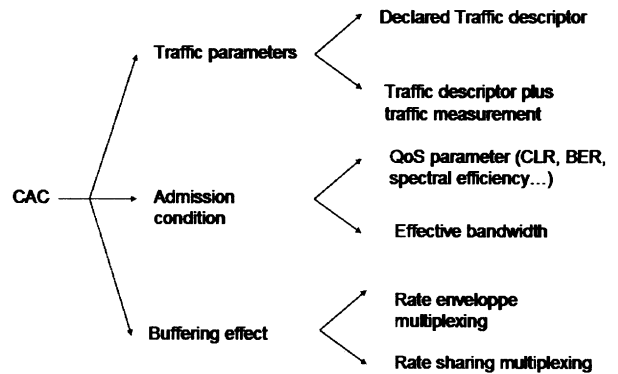

Fig. 1. CAC function clasification

Those algorithms rely on the propagation channel atmospheric attenuation and their probability density function (pdf). [ALOU] gives information on the channel characterization and modelling in ka-band systems with VSAT terminals.

B. CAC mechanisms

1) presentation: The usual CAC function can be classified according three bases as decribed on Fig. 1

The first basis for classification is the traffic parameters. That is whether the CAC function uses the declared traffic descriptor only (traffic descriptor based CAC) or uses measurement as well (measurement based CAC). For the traffic modelling, not only the number of requests but also the statistical properties of the information transmitted for the requests are important. A number of traffic models appears in the literature classified into two categories: on the one hand, there is a search for models that capture the relevant statistical properties of a specific kind of traffic from a source as accurate as possible. A good traffic model will not only capture the first moment of the statistics, but will render higher order statistic as well. This is the case of measurement-based CAC. On the other hand, there are models based solely on a few parameters extracted from the traffic characteristics. These parameters (peak rate, burstiness, average rate, and some tolerances) are insufficient to fully describe a traffic stream; also, except peak rate, the parameters are not very reliable. However, they can be used to generate upper bounds on loss and delay of traffic. This is used in traffic-descriptor-based CAC.

The second basis is whether the CAC function evaluates QoS parameters or the effective bandwidth (EB method). In the former case, the CAC function uses the traffic parameters to evaluate some QoS parameters (BER, CLR, spectral efficiency) that are compared with the system QoS objective; and connection are admitted only if the expected QoS is reached. The calculation can be complicated and heavy whereas CAC procedure must be held on a real-time basis. The EB method is similar to the admission decision procedure in a conventional multirate circuit-switching network. If sufficient bandwidth exists to support the effective bandwidth, the connection is admitted; otherwise it is rejected. Thus, admission decision process is quite simple.

The third basis is whether the buffering effect is taken into account. The CAC function can benefit from the statistical multiplexing in the buffer and the queuing process of different sources (rate sharing multiplexing). A high efficiency can be achieved in this case, but it requires a fair amount of processing power and the performances rely on the input traffic model. If the queuing process in the buffer is considered on a connection basis then any assumptions on burst length or inter-burst length distribution are not needed. Therefore the processing is not heavy.

2) CAC mechanisms: a survey: The combination of the different parameters described above give some CAC categories. PBAC (Parameter-based Admission Control): declared traffic characteristics are used by the CAC function to estimate the amount of resource needed by the terminal requiring the connection admission. In IP networks, it is difficult to obtain a priori parameters that accurately characterize flow traffics, due to the heterogeneous nature of the flows they carry. In order to obtain guaranteed resources (when admitted), flows provide a priori parameter estimates which represent their worst-case behaviours. This causes over-booking of network resources which results in low network utilization. Utilization is even lower when the flows are bursty.

MBAC (Measurement-based Admission Control) : This CAC makes admission decisions based on the estimation of parameters of an existing traffic. Every MBAC has two components: a measurement procedure for estimating current network load; and an algorithm which uses the load estimate to make admission decisions. MBAC provides higher utilization of network resources. Also, it is assumed that the statistics of the aggregate flow is easier to estimate than those of individual flows. MBAC have been found to show preference for flows with smaller resource requirements, and flows whose paths have smaller number of hops.

EAC (Endpoint Admission Control) : The hosts (the end-points) detect the level of congestion by probing the network; the host admits the flow only if the detected level of congestion is sufficiently low. It is much like the traditional IntServ approach but it does not require any explicit support from the routers; routers keep no per-flow state and do not process reservation requests and routers drop or mark packets in a normal manner. But, the substantial set-up delay limits its appeal for certain applications.

PAC (Policy-based Admission Control) : PAC not only considers network resources but takes into account policies based on security, user and application, time of day or week, and possibly other criteria. It can thus be used with other classical CAC functions. According to [RFC 2753] PAC mechanism should allow an old state to be replaced by new state, should support multiple styles of policies and relative priorities between different policies, should be able to adjust to changes in the network due to failure or structural changes in the network, should be handled by nodes that are not capable of using the protocol and should prevent from theft of services or denial of service.

V. CAC FOR CAPACITY VARYING SYSTEMS: REQUIREMENTS

Most of the CAC mechanisms described in the literature deal with constant capacity. The assumption in those mechanisms is that the capacity is well known and constant. When IFMT are used, capacity changes due to the different IFMT modes that can be activated. Development of new CAC mechanisms is thus needed. An example of such a CAC is the RCCT CAC[2], a CAC policy for stochastic capacity change times which uses knowledge about future capacity changes to provide dropping guarantees on an individual connection basis and which achieves blocking performance close to the lower bound.

The elaboration of a specific CAC for capacity-varying according to propagation conditions requires a new architecture based on a new admission control strategy and a connection rejection strategy. A major property of that kind of performing CAC is its capability to adapt to the traffic. Considering these two constraints, it appears that an optimised CAC for capacity-varying system must combine a channel prediction (for capacity variation estimation) and a traffic prediction (to adapt to new multimedia application that can appear). That CAC must so incorporate a channel prediction function that exploits, for instance, some fading and inter-fading statistical properties. The traffic prediction strategy requires to make measurement of the traffic and not to rely on some a priori traffic parameters which are, for most of the time, not reliable. Furthermore, QoS parameters must be considered because equivalent bandwidth, due to inefficient bandwidth utilisation, does not reach new systems objective that is to obtain the best spectral efficiency. Another point is to develop a rejection policy i.e which admitted connection must be dropped when deep attenuation occurs on the communication link? And how this policy can be applied in an IP based multimedia system?

A proposed architecture for this CAC is shown in Fig. 2

The "Classifier + traffic estimator" must make the measurement on the traffic flow and estimate the capacity needed by the required connection.

The "current information controller" collects information on the overall traffic flow already admitted. It contains information like the capacity allocated to each connection, the number of connections, the duration of each connection, the priority level and the traffic class of the connections. It is interfaced

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[2]CAC RCCT is a variation of the CAC based on ALC (Admission Limit Curve) which anticipates the capacity variation in time; introducing, thus a predictive character which aims mainly to optimize the a priori dropping of admitted connections. The theoretical principle of that CAC is illustrated in [SIWK]. Its admission strategy derives from the definition of the ALC which defines the conditions under which any conforming CAC shall reject a connection. It also guarantees the lower bound for dropping probability of a connection. The elaboration of that CAC requires the knowledge and the exploitation of the capacity changing times. The RCCT CAC strategy was built for Low Earth Orbit satellite systems, but its principles do not exclude other satellite communication systems like geostationary satellite multimedia systems. This CAC relies on those assumptions:
- stochastic capacity changing moment
- Connection dropping policy based on a Last Come First Drop method
- Mono-class traffic (traffic is thus a homogenous class)
- Connections follow a Poisson traffic model
- Connections duration are independent stochastic variables
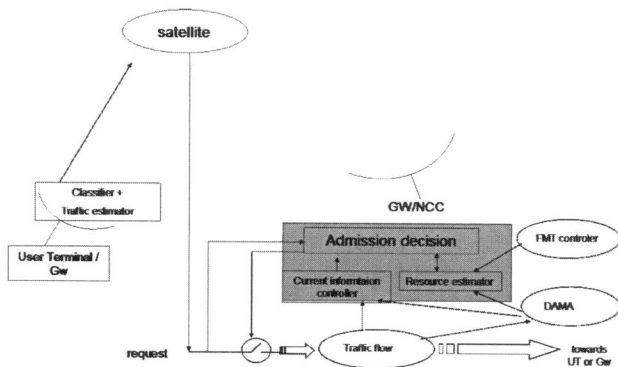
Fig. 2. Capacity-varying CAC architecture

with the DAMA controller to obtain information on the amount of resource allocated to the admitted connections.

The "resource estimator" estimates the current capacity and its possible evolution (it can rely on the CAC RCCT). For that purpose, it is attached to the FMT controller which receives the quality measurement made by ST. It also interacts with the DAMA controller to have information on the remaining capacity

The "admission decision" decides whether to accept the connection, when relying on the information provided by the other CAC blocks.

VI. OUTLOOKS AND CONCLUSION

The development of the generic CAC defined hereabove will be executed on an OPNET platform, or a more real-time oriented platform that is closer to the real system; the latter is provided from IST SATIP6 [SATIP6] project, carried by Alcatel.

Simulations will be performed keeping in mind three criteria. First to bring out the pertinent parameters needed to fully characterize multimedia traffic flows; and second to find out the appropriate method to estimate system capacity variation. To perform the latter basis, one needs to verify the pertinence of the attenuation theory given in the literature. Finally the simulation leads to compare the performances of classical CAC function in a capacity-varying environment.

The results of the simulation will give ideas of the kind of CAC to be used on capacity-varying telecommunications systems; and the traffic modelling method and the capacity variation estimation enables to build appropriate CAC algorithms. This CAC should integrate the attributes of those described in this paper.

This first year thesis document underlines the attributes of a CAC in capacity-varying environment: traffic estimation method and capacity variation prediction. For that purpose, the architecture (fig 2.) introduces the interfaces between different functions in the resource control centrer.

As perspectives, the different parameters which effectively characterize multimedia traffic and which permit the traffic prediction shall be pointed out. Also, fade probability density functions (statistics of attenuation on the communication links)

are required for the prediction of the capacity variation. Finally, one should think about the way to implement a dropping policy in an IP based network.

REFERENCES

[DVB-S2] "Digital Video Broadcasting (DVB) - Second generation framing structure, channel coding and modulation systems for Broadcasting", Interactive Services, News Gathering and other broadband satellite applications, ETSI EN 302307 v1.1.1, Janvier 2004.

[DVB-RCS] "Digital Video Broadcasting (DVB)-Interaction Channel for Satellite Distribution Systems", ETSI EN 301790 v1.3.1, March 2003.

[ESA4223] "Integrated resources and QoS management in DVB-RCS networks" I22nd AIAA International Communications Satellite Systems Conference,Monterey, May 2004. S. Combes, L. Goegebeur, N. Sannier, M. Fitch, G. Hernandez, A. Iuoras, S. Pirio

[ESA 4135] "Adaptive Coding Modulation techniques for Ka and Q bands", ESA/ESTEC contract 16533/02/nl/EC

[PECH] "Incidence de la prise en compte des effets de mécanismes de lutte contre les affaiblissements (FMT) en bande Ka sur la gestion des ressources dans un systeme d'accès multimédia par satellite géostationnaire", Ponia PECH, Thèse ENSAE,Décembre 2003.

[SAGAM] "Satellite Géostationnaire d'Accès Multimédia", a RNRT -Réseau National de Recherche en télécoms- project

[SATIP6] http://satip6.tilab.com

[CAST] "Comparaison of various methods for combining propagation effects and prediction loss in low-availability system in the 20-50 GHz frequency range" L. Castanet et al. Inter. Journal on satellite communication, vol. 19, 2001

[ALOU] "Channel characterization and modelling for Ka-band VSAT terminals". M. Alouini et al. Proceedings of the IEEE. vol.85 june 1997

[GOLD] "variable rate variable power MQAM for fading channels" A. Goldsmith, Soon Ghee Chua. IEEE transactions on communications. vol.45, oct. 1997

[GAUD] "Adaptive coding and modulation for next generation broaband multimedia system" R. de Gaudenzi, Rita Rinaldo. American Institute of Aeronautics and Astronautics paper. AIAA-2002-1863

[SHIO] "Overview of measurement-based connection admission control methods in ATM networks"K. Shiomoto et al. IEEE communications Surveys. 1999

[SIWK] "Connection Admission control for capacity varying networks with stochastic capacity change time" J. Siwko and I. Rubin. IEEE ACM transactions on networking. vol.9 june 2001

[JIAN] "Measurement-based admission control: a revisit". Y. Jiang and al.

[RFC 2753] A Framework for Policy-based Admission Control

ACRONYMS

ACM Adaptive Coding and Modulation
ALC Admission Limit Curve

ARC Access Resource Control
ATM Asynchronous Transfer Mode
BoD Bandwidth on Demand
CAC Connection Admission Control
DAMA Demand Assignment Multiple Access
DRR Dynamic Rate Reduction
DVB Digital Video Broadcasting
DVB-RCS DVB with Return Channel for Satellite
DVB-S2 DVB second generation
ESA European Space Agency
ETSI European Telecommunication Standards Institute
IFMT Interferences and Fade Mitigation Techniques
IntServ Integrated Service
IP Internet Protocol
QoS Quality of Service
RCCT Random Capacity Change Time