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A Survey On Packet Scheduling Over DVB-S2 Through GSE Encapsulation

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***Abstract*—A key features of the second generation for video broadcasting (DVB-S2) is the adoption of Adaptive Coding and Modulation (ACM) technology and the Generic Stream Encapsulation (GSE). In order to increase the system performance up to the Shannon limit a suitable resource management (RRM) exploiting this key features is a needed. Packet scheduling mechanisms particularly play a fundamental role to guarantee a better RRM, because they are responsible for choosing, with a fine time how to distribute the satellite resources among different terrestrial stations, taking into account channel condition and the quality-of-service requirements. This goal should be accomplish by providing, at the same time, an optimal trade-off between spectral efficiency, given the limited resources on satellite systems, while granting the requirements for quality-of-service. In this context, this paper provides an overview on the key issues that arise with the use of ACM technology and GSE encapsulation in the design of a scheduler to allocate satellite resources. Moreover, a survey on the most recent scheduling techniques is reported, including a comparison between different approaches presented in literature.**

Keywords*—*DVB-S2, ACM, GSE, Packet scheduling .

I. Introduction

In the last years, the demand for IP-Based services and their users have been increased. As a consequence, quality-of-service (QoS) must be considered. To provide this type of IP-services, the geostationary satellite infrastructure plays a fundamental role, Nevertheless they have also some drawbacks that affect the quality-of-service provisioning such as variable link capacity, high propagation delay, packet corruption and the channel asymmetry. this drawbacks need to be considered to preserve the quality-of-service levels when the atmosphere experience the rain events, which can also reduce the available capacity in the DVB-S2 forward channels. Toward this end, a great importance is given to the Adaptive Coding and Modulation (ACM) technology and Generic Stream Encapsulation (GSE). In addition, the ETSI-BSM working group has specified a quality-of-service functional architecture. This framework establishes a specification based on the internet protocol for providing quality-of-service to broadband satellite multimedia service. In order to increase the performance of the system up to Shannon limit, packet scheduling play a crucial role, because they are responsible of the satellite resource allocation, taking into account channel conditions and quality-of-service requirements. The issue of scheduling has been widely addressed, focusing on various objectives and using different approaches, ranging from classical approaches based on Weighted Round Robin to Cross layer optmization and Utility function and its derivatives. Scheduling can be defined in a DVB-S2/DVB-RCS network as the operation of choosing which IP packets to put in a Broad-Band Frame (BBFrame) and which BBFrame to transmit next. Each BBFrame is characterized by a single ModCod. The use of ACM technology allows the gateway to enable transmission of each BBFrame with the most appropriate ModCod. The adaptation of the ModCod is done on the basis of frame-by-frame. The size and the transmission time of a BBFrame change according to the modulation and coding used to transmit this one which make decision not trivial. The paper is organized as follows. Section 2 of this paper presents an overview on DVB-S2 . Section 3 present various approaches used to tackle the issue of scheduling ranging from classical approaches based on round robin to Cross Layering and the Utility function, then a comparison between different approaches both, in terms of performance and complexity. Finally, conclusions are drawn showing the potentiality of rule based scheduling approaches.

II. Description of the system

The system is composed of a GEO satellite, a gateway serving multiple users. The forward channel is from the gateway to the terminal RCST. The return channel is from the RCST to the gateway. The forward link uses the DVB-S2 and the return channel uses DVB-RCS.

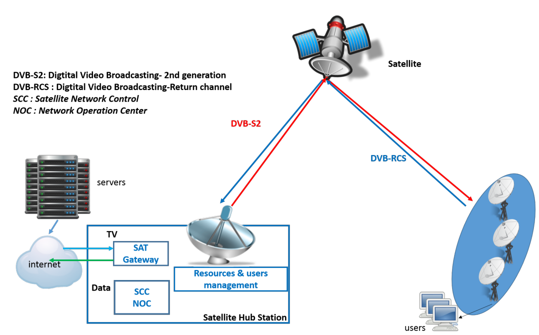

Fig. 1. Architecture DVB-S2/RCS

A. DVB-S2

DVB-S2 [1] is the second-generation DVB specification for broadband satellite applications developed after the success of the first generation specifications by digital video broadcasting group in 2003. The DVB-S2 standard has been specified around three key concepts: best transmission performance, total flexibility and reasonable receiver complexity. The Benefits of DVB-S2 from the last improvement in terms of technique of modulation (use of QPSK, 8PSK, 16APSK and 32APSK) and channel-coding (use of LDPC codes) which allows to the standard to increase the performance in terms of spectral efficiency by 30 per cent comparatively to the first generation. To benefit totally from this flexibility the standard allows the use of GSE encapsulation and ACM technology.

B. Generic Stream Encapsulation

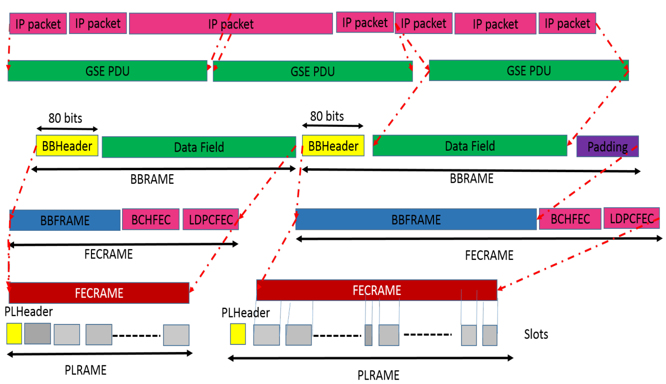

Fig. 2. Air interface architecture of the DVB-S2 using GSE encapsulation

One-steps of DVB-S2 is the use of GSE encapsulation. IP packet are encapsulated into BBFrame though GSE encapsulation as illustrated in the figure 2. It should be noted that multiple IP packets can be encapsulated into one BBFrame. This BBFrame is encoded according to the selected ModCod to form a FECFrame of a fixed length (normal length: 64800 bits, or short 16200 bits). Each BBFrame support one ModCod and its length change according to the ModCod used. If this one is not totally full, padding can be added.

C. Adaptive Coding and Modulation

One of the main features of DVB-S2 is the adoption of the ACM technology, which has been considered as a powerful tool to further increase system capacity. The ACM is dedicated for interactive applications such as access to the internet. The use of the ACM technology allows the transmitter to adapt the modulation and the channel coding (ModCod) to the transmission conditions for each terminal user. Figure 3 shows the basic behavior of the ACM technology in which every Satellite Terminal(ST) calculate its SNIR and report it to the gateway; according to the value of SNIR calculated, the gateway enable the transmission with the most suitable ModCod. Each SNIR correspond to one ModCod and each BBFRrame supports only one ModCod. The adaptation of the ModCod is done based on the frame-by-frame.

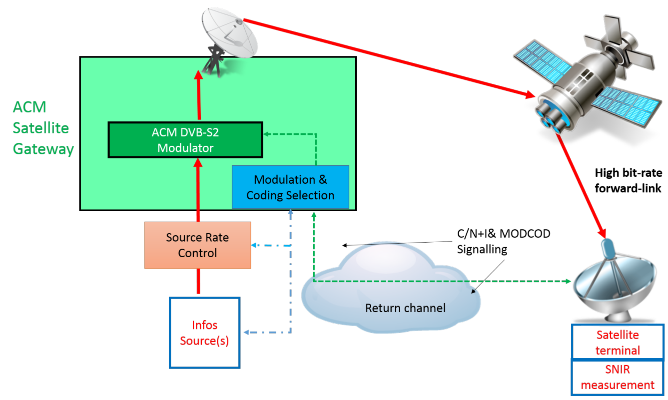

Fig. 3. Adaptive Coding and Modulation

III. Packet Scheduling Over DVB-S2 Through GSE Encapsulation

Scheduler in DVB-S2/DVB-RCS have to take into account different aspects in The process of allocation of resources in which the scheduler decide which quantity of resources have to be allocated to each user terminal. GSE packet scheduling remains a major issue because it faces conflicting objectives: maximizing spectral efficiency is mandatory given the scare resources on satellite systems, while granting the requirements for quality-of-service. Furthermore, Because of the huge size of the BBFrame, multiple GSE packets with different needs in terms of ModCod and quality-of-service requirements can be encapsulated into a single BBFrame. The decision with which ModCod transmit this BBFrame and which GSE packets serve on it is not trivial. In addition, the size of a BBFrame change from one ModCod to another which increases the complexity of scheduling. Each user terminal calculate its SNIR and report it to the gateway who use this information to enable transmission with the most appropriate ModCod. The satellite network is characterized by a significant delay. In this time, condition of transmission could be changed which could increase the risk to use a ModCod not appropriate to the current transmission.

A. Round Robbin based scheduler

Let us Consider a total of packet flows, each packet flow has its own packet queue,sharing an output link at the router. Each flow maintains a separate queue of its packets waiting for access to the transmission link. The basic behavior of WRR as described in [2] is: First, the classifier in the router puts each incoming packet into the queue of the corresponding flow. Secondly, the scheduler accesses each queue in a round-robin fashion. The maximum number of packets allowed to be transmitted from a queue in a round is specified by the weight for the queue. This weight is a predetermined constant integer according to the requested bandwidth. In order to calculate the optimal weight values based on the quality-of-service requirements, different criteria have been used (e.g. the mean packet size, queue size, capacity of DVB-S2 satellite link. In [2], a Variably WRR (VWRR) scheduler is proposed. This model uses the average packet length to adapt its weights. A weight value is calculated considering two parameters: the bandwidth requirements and the average length of packets.

A resource allocation model considering the average queue size, which is calculated using a low-pass filter is proposed in [3]. In [4], an adaptive scheduling scheme using the revenue-based WRR is presented. The proposed approach has been considered for guaranteeing the maximum service provider revenue. The proposed scheme, adjusts its weights using the revenue criteria to control the resource allocation. In [5], a modified Fair WRR (FWRR) scheduler has been proposed to protect the best effort traffic from the assured forwarding out-of- profile packets in the core routers based on the DiffServ architecture. This policy dynamically adjusts the weights and the buffer allocation using congestion hints to avoid unfair bandwidth. In [6], an adaptive WRR scheduler is proposed to manage the quality-of-service and to optimize the utilization of the DVB-S2 satellite link capacity. This model aim to share the available bandwidth between the various service classes having a certain quality-of-service level. The proposed adaptive scheduler calculates the optimal weight values considering the current capacity of DVB-S2 satellite link as the main criteria for the allocation of network resources by applying two functions that associate the weights of the higher priority classes and the satellite link capacity: a linear and an exponential weight function. in WRR,Each queue has its own integer weight .The server visits all queues in a Round robin cycle. When the server visits any queue, it serves the packets of queue up to a maximum of weight, in a first-come-first-served manner. The main inconvenient of this approach is that WRR does not work efficiently for networks with variable length packets, which have a fairness problem since WRR usually allocates the bandwidth on a packet-by packet basis. DRR (Deficit Round Robin) [8] is a new version of WRR to improve the fairness. [7] Define an isolation mechanism that achieves nearly perfect fairness in terms of throughput. Although DRR is simple enough to be implemented or combined with others schemes. WRR and its derivatives generally allow achieving good performance, however the cost of a weight-tuning that is not always straightforward, especially for dynamic systems, deemed to be adaptable to deeply varying transmission situation.

B. Two Step Scheduler

Two Step Scheduler aims to build a new scheduling approach able to take into account the quality-of-service requirements and ModCod parameters. As can be seen in the figure 4, this structure as defined in In [9] by Prraga et al. is characterized by a two level architecture : The first step consists on choosing which users to serve and the second step is dedicated to select the next BBFrame to transmit.The proposed architecture presents some important components including the queue manager, the queue scheduler for the first step process and the MAC- framer and the MAC-scheduler for the second stage. In [10] Tropea et al. propose an enhanced version of two step scheduler stage (TSS) based on the adaptive and priority scheduler for the first stage of TSS called adaptive priority-based scheduling (APS) and ratio and a revisit of the proportional fair queuing (PF) called PFmod for the second stage. The results showed that the couple composed of APS plus PFmod presents the best performance in terms of drop rate, jitter and packet delay. Classical approach based on two step shows good performances and low scheduling complexity. However, it is difficult to parameter mainly because of the two distinctive scheduling steps.

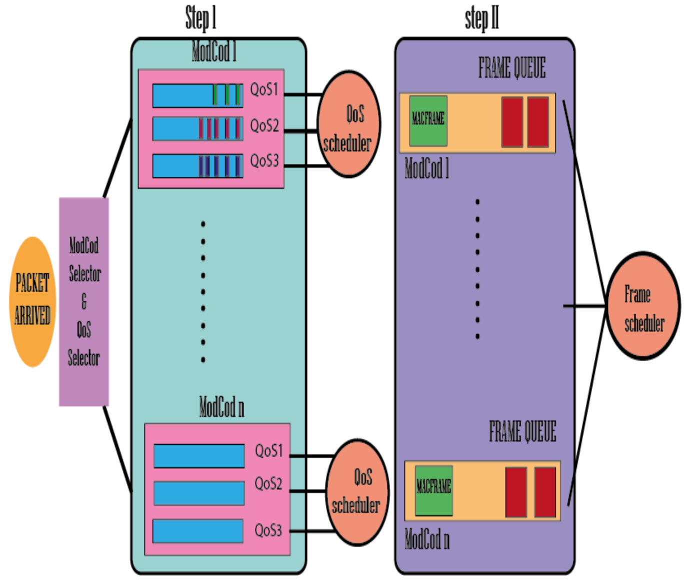

Fig. 4. Two step scheduler structure

C. Scheduling and Cross Layer optimization

the fundamental objective of Cross Layering optimization is to exploit physical layer adaptation as much as possible across layer. The idea beyond Cross Layer Design is to establish a communication between non-adjacent layers. In the case of scheduling, a cooperation between Physical Layer Protocol and the Network Layer Protocol is needed to built a joint scheduler that takes into account various constraints such as quality-of-service requirements and the satellite channel characteristics. An example of using Cross Layer Design is the QoSatAr presented by R.Morales et al. in [11]. the design of QoSatAr is done in compliance with the ETSI-BSM-quality-of-service architecture and the standard DVB-S2 while adopting the DiffServ framework to guarantee the required quality-of-service specification in the SLA. the main objective of this architecture is that the IP scheduler provide quality-of-service guarantees among DiffServ flows while reducing latency and jitter values considering the physical layer changes due to the ACM adaptation behavior. This is done via a cross layer between the physical layer and the network layer as illustrated in the figure 5. The scheduling policy is assumed to be WRR. In [12], the authors investigate a novel cross layer design that allows using channel related knowledge to the packet scheduling for the forward link to provide tunable fairness. The major novelty is given by the fact that the proposed algorithm also supports differentiation of services that comply with the requirements for implementing quality-of-service. This approach assumes that scheduling policy is to be Weighted Round Robin (WRR) , where the weights depend on the spectral efficiency of each ModCod, balanced by a fairness parameter which is set according to the type of traffic. This is a yet another example given in [13], where the authors present a full cross-layer design of a DVB-S2 based satellite system for unicast services provisioning quality-of-service guarantees. On the basis of work done in [12], the author propose a new approach that exploits the satellite channel characteristics

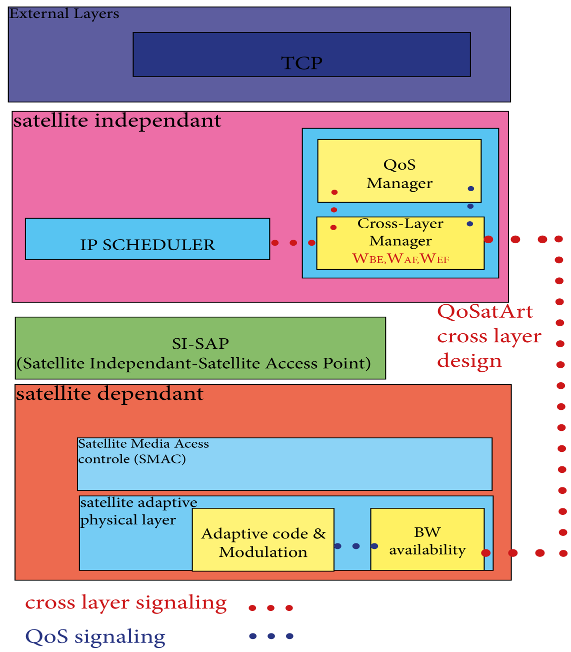

Fig. 5. The cross-layer design for the IP scheduler

of the time and space correlation via a Cross-Layer queuing architecture and an adaptive scheduling policy that supports different fairness policies. The hierarchical scheduling consists of the following policies: Tunable-Fairness Weighted Round Robin (TF-WWR) policy that provide the preferred fairness and the second policy based on the Adaptive Weighted Round Robin (AWRR) provides the quality-of-service guarantees in terms of delay, jitter and packet loss. As for the quality-of-service model, they assume an IETF differentiated Service (Diffserv) model. The results reported in the paper [13] show that their approach not only allows system load control but also rate adaptation to the channel conditions and traffic demands on the coverage area. The trade-off between system-wide and individual throughput is illustrated by means of simulation, and this trade-off could be a key metric in measuring the service level of DVB-S2 Broadband Service.

D. Utility Function

The main objective of Utility function is to allows to encompass several parameters into a single scheduling process. Utility function $U(s)$ as defined in [15] describes how an application can benefit or (suffer) from a service s . The service s may be a simple scalar metric or a tuple encompassing many parameters such as throughput, delay, loss rate, or jitter. Chaput, et al. in [14] believed that the use of Utility function could be a great help for the problem of packet scheduling over DVB-S2 which has been successfully applied in wireless network . A shortcoming of Utility function based scheduling is that the search of optimal could be very expensive. In fact, the theorical optimum changes over time and has then to be considered for each scheduling decision. A resolution through the knapsack is proposed in [14]. The authors have shown that a knapsack algorithm could be both efficient and affordable and how fragmentation and classification can be used to improve performances. Another challenge is how to translate the high level quality-of-service specification into utility function. An attempt to reach the utility function to take into account quality-of-service differentiation is made in [15]. This paper addresses the problem of GSE packet scheduling over DVB-S2 with quality-of-service support by adopting utility function based scheduling strategy. This paper attempts to propose an algorithm to tackle both the application level quality-of-service requirements and the spectral efficiency optimization. The metric used to represent quality-of-service requirement in this algorithm is the delay. The simulations results reported in [15] show that Utility function based scheduling allows to achieve lower maximum delay and how best performance can be achievable without need of any parameter tuning or adaptation. It is however difficult to operate such algorithms in real time due to their complexity. To overcome this issue, a resolution through gradient ascent and optimization algorithms is proposed in [15].

E. Rules Based Scheduler

The high computational cost of the latest approaches based on utility function has lead dupe et al. in [16] to adapt successful scheduling rules defined in the terrestrial wireless networks known as PF(for proportional fairness), Modified Latest Weighted Deadline First (M-LWDF) and Exponential rule (EXP-PF) for both quality-of-service and ModCod scheduling. Scheduling rules, inherited from utility theory is an efficient way to build a joint scheduler who could encompass several parameters into a single scheduling process. They consist on a function, defined for each user, evaluated at every scheduling decision. To adapt scheduling rules to the context of Packet Scheduling over GSE/DVB-S2, the authors defined two rules: the user rules and ModCod rules. User rules is defined for each user, taking into account various parameters relevant to this particular user, such as rate, delay,loss rate. ModCod rule is a function of the user rules belonging to this ModCod, thus encompassing user needs, but also adds parameters belonging to this ModCod: payload and transmission time. Selection of IP packets within a BBFrame is done via user rules, and ModCod selection is done through ModCod rules. The continuous usage of the same functions allows to provide a coherent scheduling scheme, from IP packets to BBFrame. Table I features the different notations we will use.

N_k	Total number of users using ModCod k
$N_k^a(n)$	Number of active users on ModCod k instant n
$\mu_i(t)$	the actual rate supported by the channel
$\bar{\mu}_i(t)$	the mean rate given to user i
W_i	Head of line delay for user i
Rk	Instantaneous rate of a BBFrame with ModCod k
$v(n)$	Transmission time of BBFrame n
$Li, k(n)$	Number of bits served for user i, ModCod k
ci, k	User i, ModCod k rule
$\gamma_{i,k}$ is	Coefficient of user i, ModCod k
ai, k is	QoS parameter, user i ModCod k
j	Selected user
m	Selected modcod

1) Proportional Fairness Rule: The Proportional Fairness rule is given by the following formula :

$$j = argmax_i \frac{\mu_i(t)}{\bar{\mu}_i(t)}$$

This rule offers a trade of between high achievable throughput and fairness; it is not throughput optimal : the adaptation of this rule is given by defining two rules : User rule and ModCod rule user rule is given by the :

$$c_{i,k}(n) = \frac{1}{\bar{\mu}_{i,k}(n)}$$

the ModCod rule is given by the formula :

$$m = argmax_k R_k \frac{N_k^a(n)}{N_k} \sum_{k=1}^{k=N} c_{i,k}(n)$$

One of the main difficulty of this approach is how to evaluate the metric which against the Rule is calculated. according to [16]the the average rate is measured by the following expression :

$$\bar{\mu}_{i,k}(n) = \alpha^{\upsilon(n)} \bar{\mu}_{i,k}(n-1) + (1 - \alpha^{\upsilon(n)}) \frac{L_{i,k}(n)}{\upsilon(n)}$$

2) L-MWDF: the expressions of the L-MWDF rules as given in [16] is:

$$j = argmax_i \mu_i(t) \gamma_i W_i(t)$$

where $\gamma_i = \frac{a_i}{\bar{\mu}_i}$ Similarly to the PF the L-MWDF rule is adapted to our context by defining , The User rule and the ModCod rule :

$$m = argmax_k R_k \frac{N_k^a(n)}{N_k} \sum_{k=1}^{k=N} \gamma_{i,k} W_{i,k}(n)$$

$$c_{i,k}(n) = \gamma_{i,k} W_{i,k}(n) \text{ and } \gamma_{i,k} = \frac{a_{i,k}}{\bar{\mu}_{i,k}(n)}$$

3) EXP-PF: EXP-PF rules are given by :

$$j = argmax_i \gamma_i \mu_i(t) exp(\frac{a_i W_i(t) - a\bar{W}}{1 + \sqrt{a\bar{W}}})$$

$$m = argmax_k R_k \frac{N_k^a(n)}{N_k} \sum_{k=1}^{k=N} \gamma_{i,k} exp(\frac{a_{i,k} W_{i,k}(n) - a\bar{W}}{1 + \sqrt{a\bar{W}}})$$

the simulation results reported in [16] show the limits The PF rule which is unstable and leads to a large delay, M-LWDF shows a large improvements compared to PF, both in terms of delay and in terms of spectral efficiency . The EXP-PF is a trade-off between PF and M-LWDF. They have shown that tuning fairness can improve performance . The rules hold a low computations cost.However some interesting indicators of performance are not yet included such as reclassification and filling ratio.

IV. Comparison between scheduling techniques

To analyze the behavior of this scheduling techniques, we focused on three parameters: the mean delay, the reclassification ratio and fairness. The delay as a metric to evaluate the quality-of-service, reclassification ratio gives an idea of the spectral efficiency and fairness WRR shows good performance for low load but it is inefficient both, in terms of delay and the spectral efficiency under high load (the mean delays beyond quality-of-service requirements, reclassification rate is high). however very basic scheduling strategies can achieve good performance (low response time, high spectral efficiency) and even with a higher load the system remains stable, with a lower benefits from reclassification and the price is a fairness degradation. utility scheduling with an explicit resolution using gradient ascent lead to mean waiting time below the quality-of-service requirements, Moreover reclassification levels is very low under high load that comfort us to the same result that The impact of Reclassification is quite marginal under high load . The optimization version of utility scheduling hence a fairer behavior but reclassification is higher which results in a lower spectral efficiency than the gradient ascent. In the case of PF and under high load, delays are potentially large and reclassification volume is poor, as a result, the proportional fairness is inefficient both, in terms of delay and spectral efficiency. Compared to PF, M-LWDF shows large improvement both, in terms of delay and spectral efficiency, the relative reclassified data being low. The behavior of EXP-PF approaches PF, leads to lower performance for high load flows. Applying fairness parameter to this rules leads to inefficiencies, as the throughput of each ModCod become fairer, the mean delay increase. To sum up, WRR, PF and EXP-PF are inefficient both, in terms of delay and the spectral efficiency under high load. Most of techniques comfort us into the same assumption that the impact of Reclassification is quite marginal under high load so it is not necessary to considerate it for high load. Very basic scheduling strategies, utility scheduling with an explicit resolution using gradient ascent and M-LWDF rule show good performance even with higher load (delay under quality-of-service requirements and higher spectral efficiency) but the price is fairness degradation. To hence the fairer behavior utility scheduling with an explicit resolution using optimization algorithm is a solution but at the price of lowering the spectral efficiency. Focusing solely on a single aspect of the problem performance (spectral efficiency, delay or fairness) lead to inefficient solutions.

V. Conclusion

All approaches we have presented in this paper generally show good performance but they dont take into account all constraints and generally focus on a single objective and dont evaluate their approaches with different criteria. In our future work we will focus on a design of a joint scheduler that is a trade-off between fairness and spectral efficiency while ensuring quality of service under high load.

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