# A Proposal Approach for Load Distribution and Resources Sharing in IEEE 802.11 Networks

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## Abstract

Recently there is a growing interest in the internet and multimedia wirless networking where the bandwidth and the QoS metrics must profoundly adjusted to the application requirement. However the problem of user bandwidth availability arises as one of the most limit of this solution. In fact, the IEEE 802.11 standards do not provide performed mechanism of loading distribution among different APs of the network. Then an AP can be heavily overloaded leading to station throughput degradation.
This paper focuses on the specification of a centralization solution for QoS management in IEEE 802.11 networks. It, mainly, presents the general architecture of the overall system based on a load balancing server over the AP(s) network resources. In addition, the paper addresses a protocol specification for AP and mobiles interactions intended to provide best resources allocation and efficiency on communication metrics. This protocol is being described and simulated with SDL and MSC tools as a first step before experimentation in real environment.

## 1. Introduction

In the last few years the IEEE 802.11 technology becomes very interesting. One of its popular uses is its cheap hardware infrastructure price promoting to provide practical and efficient Hotspots environment [1].
The research work [1, 2, 3, 5] carried in this context had proved that additional effort is yet required to build up a system with a high service quality. A specification of further interaction in the IEEE 802.11 protocol between AP and the mobiles mainly in call admission will help to ensure some QoS parameters such as loading distribution and packet losses [1, 2, 4, 19, 20]. A new standard has IEEE 802.11e [21] has been defined to ensure quality of service in Wireless LAN.

This paper presents a protocol specification managing the QoS in the context of Hotspots communication environment. The first part focuses on the description of the general hotspots environment architecture. The second part presents the load balancing algorithm. In the next part we define of new protocol primitives between the mobile and the access point managing QoS metrics. Then we present the description of this protocol with the SDL (Specification and Description Language) language [8, 9] and some MSC (Message Sequence Charts) simulation results of the behaviour of this protocol. We finish by highlighting future contributions in this field.

## 2. General approach presentation

The QoS management on hotspots environment becomes vital as many new emerging applications such as mobile information access, real time multimedia communications, networked games, immersion worlds and cooperative work require a minimum level of QoS [12, 13, 17, 18].
The hotspots environment can be described as a set of access points covering overlapping cells and offering connection to a variable number of mobile stations. User's applications are not similar in terms of QoS requirements so that a fair distribution of the mobile stations among active access points can guarantee a minimum level of quality of service. The bandwidth effectively offered by an access point is given by the following formula (Shanon). BP is the bandwidth defined by the IEEE 802.11 standard.

$$Cmax = BP \times \log_2 (1 + SNR)$$

So, due to the wireless environments (interferences, obstacles…) bandwidth is scare and channel conditions will be time-varying and sometimes highly lossy.
Unfortunately, in the actual IEEE 802.11 protocol, a mobile station is associated to the access point offering the best Signal by Noise Ratio (SNR) independently of the load being applied to the access point by other users. This can cause, in many cases, unbalanced load between access points.

Some access points will be over loaded, others are under loaded. For the first ones applications requirements are not fulfilled. The keystone of our approach is to associate mobile station to access points with a minimum SNR threshold and offering the best QoS level.

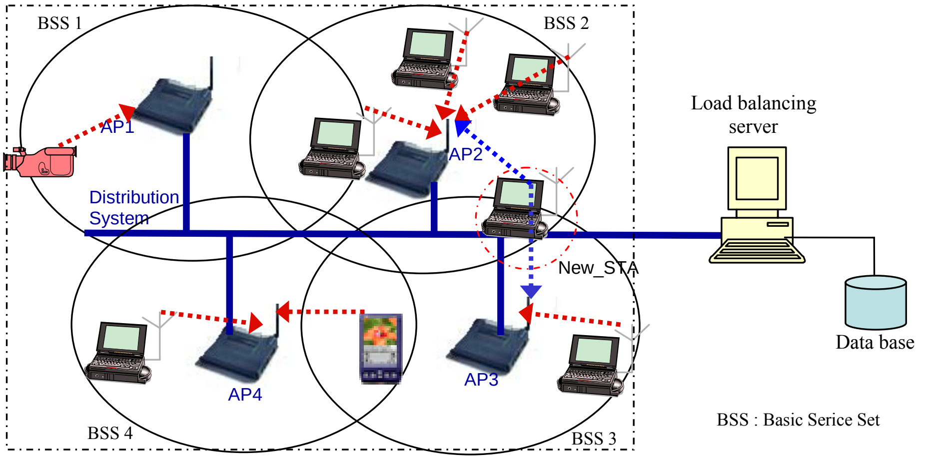


**Figure 1.** IEEE 802.11 target architecture

Figure 1 sums up the idea we develop in this paper. A new mobile station (New_STA) reaching the WLAN must be associated with an access point. The association procedure is always initiated by the station (mobile-controlled handover) and the station can be associated with only one access point. The New_STA must discover which access points are present and then requests to establish an association with one of them. Thus, first the station initiates a scanning process that can be either active or passive [6]. Once the scanning process has finished, the station has an updated list of access points in range (AP2 and AP3).
This information is used by the station to associate with the access point that provides the higher Signal-to-Noise Ratio (SNR).
Let's suppose that AP2 is chosen by New_STA. The load distribution across access points will be highly uneven [1]. This can cause a performance degradation perceived by the other stations attached to AP2. Quality of service contracts (bandwidth, loss rate…) may be violated. It will be attractive to associate the new host to AP3 which has lower SNR but is under loaded. So that we fulfill the QoS requirements of both old and recent associated stations: the available bandwidth of the WLAN link depends strongly on the number of active stations and their traffic. To achieve this balancing, in terms of quality of service offered to the stations (load, loss rate…) among access points, we have to compute a balancing algorithm each time a new event such as the arrival of new stations or the mobility of existing stations. This algorithm has to find the best state of associations between access points and mobile stations that offers the best quality of service level for user's applications. Thus, we have to get information on associated stations, traffic coursed by access points and users quality of service requirements (Figure 2). This information has to be exchanged between WLAN entities and stored in an updated data base.

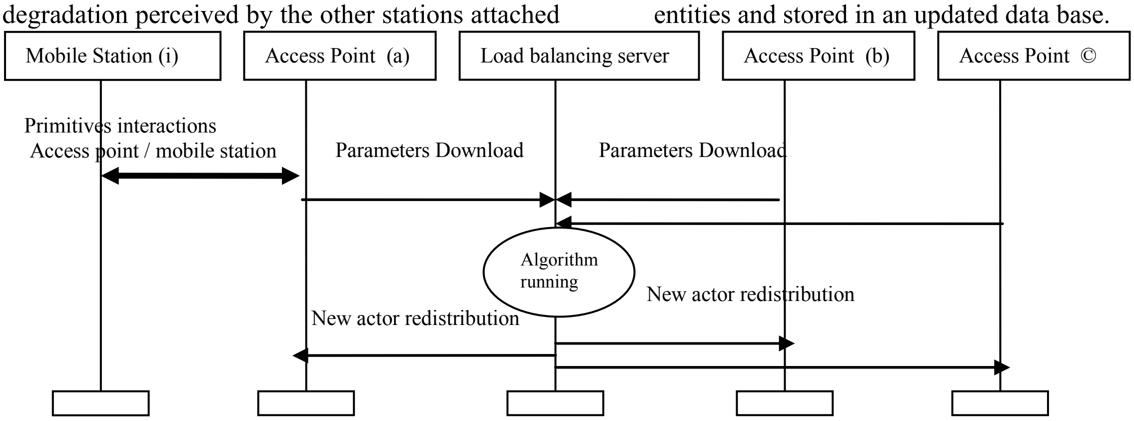


**Figure 2. :** System protocol interactions

In this architecture the load balancing server should periodically download a set of specific parameters from each access point. It runs up the balancing algorithm finding the best mobile station sharing among the available access points. The result will then be broadcasted in the system. Then, we have defined for this architecture a set of new metrics to quantify the quality of service and primitives exchanging these parameters for association and disassociation between mobile station and access point. These primitives that should be inserted into the MAC layer to improve the IEEE 802.11 standard [14] define a new MAC quality of service policy for wireless LANs.

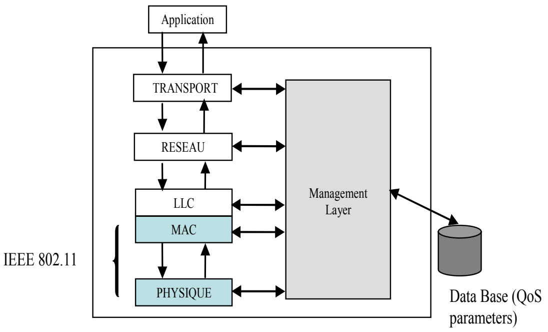


**Figure 3.** System exchange design

## 3. Load balancing algorithm description

### 3.1. Functional description

As shown in Figure 2, the load balancing algorithm [15, 16] is computed by the load balancing server every time a new distribution is needed in the wireless LAN. This will occurred (i) when a new mobile station enters the wireless LAN and aims to associate with an access point, (ii) when an associated station is moving from one to another BSS (iii) and when the applications requirements in a mobile station are changing. The downloaded parameters from the access points and mobile station applications will be useful to find the best distribution of mobile stations among wireless LAN access points.

This algorithm checks if the new distribution is balanced mainly by computing the balance index (β). The balance index appeared in the first time in [11] and it is used in [2, 15] as a performance measure. The balance index reflects the used capacity in each access point. Let Ti be the total traffic of the APi. Then, the balance index is:

$$\beta j = (\Sigma_i Ti)^2 / (n * \Sigma_i Ti^2)$$

β j is the balance index of an overlapping zone j.

Ti is the total traffic of an APi overlapping with other access points in the zone j.

n is the number of access points overlapping in the zone j.

The balance index varies in the interval [1/n, 1]. The proposed distribution of mobile stations is balanced if the balance indexes of all the overlapping cells converge to 1. An AP is overloaded if its load exceed a certain threshold $\delta_1 = ANL + \alpha.ANL$. It is balanced if his load is in the interval $[\delta_1, \delta_2]$, $\delta_2 = ANL - \alpha.ANL$. An AP is under loaded if his load is under $\delta_2$.

ANL is the Average Network Load.

α is a tolerance parameter that define the balancing zone width. To balance the WLAN, stations are moved from the uploaded to the under loaded access points. The question is: witch station to move? A selection policy is to make in place.

Our approach is defined as follow:

- The algorithm calculates the difference Δ between the most uploaded access point and the ANL ($\Delta = T_{APsurchargé} - ANL$).
- The station that the flow is nearest to Δ is the selected station to move.

This work will be repeated until there is no over loaded access point in the WLAN.

At this step, the algorithm has to send the new distribution to the access points which will be authorised to dissociate, associate and reassociate mobile stations.

### 3.2. Algorithm application

We present an example of wireless LAN with three access points AP1, AP2 and AP3 linked with a distribution system and a set of mobile stations. For each station we have define the number and the traffic load. We suppose that the generated traffic is static.

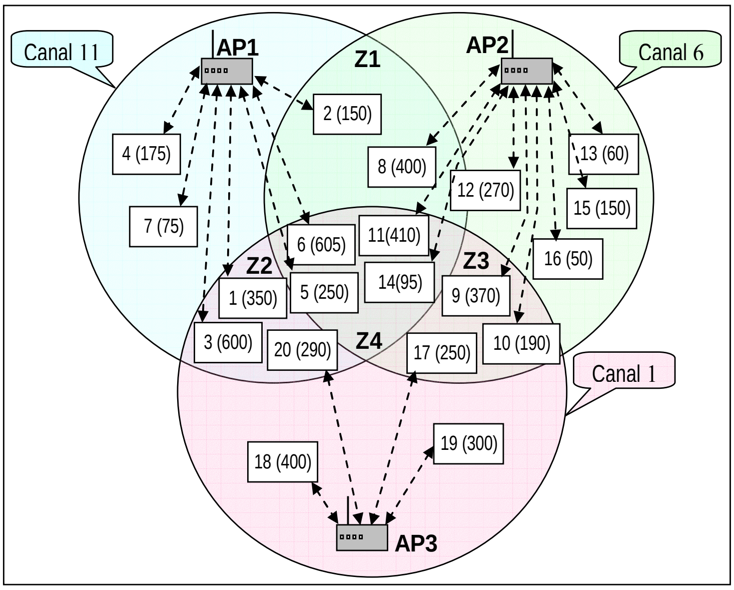


**Figure 4.** Unbalanced wireless LAN

In table 1, we describe the hot spot architecture. In this hot spot ANL=1813.333, $\alpha$=5%, $\delta_1$=1903.999 and $\delta_2$=1722.667. In this hot spot, there are four overlapping zones (Z1, Z2, Z3 and Z4). In table 2, we illustrate the characteristics of the overlapping zones.

**Table 1.** Hot spot description

| Access Point | $AP_1$ | $AP_2$ | $AP_3$ |
|---|---|---|---|
| Mobile station identification | 1, 2, 3, 4, 5, 6, 7 | 8, 9, 10, 11, 12, 13, 14, 15, 16 | 17, 18, 19, 20 |
| Access point load (Kbps) | 2205 | 1995 | 1240 |

**Table 2.** Overlapping zones characteristics

| Zone | Z1 | Z2 | Z3 | Z4 |
|---|---|---|---|---|
| Access Points | AP1, AP2 | AP1, AP3 | AP2, AP3 | AP1, AP2, AP3 |
| Stations | 2, 8 | 1, 3, 20 | 9, 10, 17 | 5, 6, 11, 14 |
| Balance index of the zone ( $\beta$ ) | 0.997 | 0.927 | 0.948 | 0.950 |

In this example we can see that AP1 and AP2 are overloaded and that AP3 is under loaded. Running the load balancing algorithm will give us a new distribution of the mobile stations among the access points. This distribution is given by the following table (table 3).

**Table 3.** New distribution description

| Access Point | $AP_1$ | $AP_2$ | $AP_3$ |
|---|---|---|---|
| Mobile station identification | 1, 2, 3, 4, 5, 6, 7 | 8, 9, 10, 12, 13, 15, 16 | 11, 14, 17, 18, 19, 20 |
| Access point load (Kbps) | 1795 | 1900 | 1745 |

## 4. Protocol specification

In this approach, the QoS management is based on the idea that some added primitives must be ensured at the connection level between the mobile station and the access point. Then, each mobile in the wireless LAN may be able to propose a level of QoS and to modify it when needed.

In this architecture, the mobile station defines four variables managing its QoS state. The communication process will then base its

negotiation with the access point on these parameters to build up clause for service quality.
To ensure QoS management in the WLAN some identifiers should be joined to the parameters describing present and old quality of service states in each mobile. These identifiers are maintained in a specific database both in the access point and the mobile station.
Each mobile station will then discuss the attachment attempt responses of the access point according to its own QoS parameters. These parameters have to be saved in a specific data base managing the whole environment of the wireless device. This database communicates with the other layers defined in the IEEE 802.11 model to ensure coordination in call admission processes.

## 5. QoS protocol primitives

The IEEE 802.11 suffers from lack of specific QoS primitives. The only parameter on which is based the connection negotiation between the AP and the mobile station is the SNR ratio. The satisfaction of only this parameter in the connection phase don't meet necessary the QoS requirements of the application. So it appears indispensable to specify new protocol primitives to enable the integration of other communication parameters in the connection decision and then in loading redistribution.
We have then, defined a set of new primitives expressing general requirements.

**Table 4**. Quality of service primitives

| Primitives | Access Point | Mobile Station | Parameters |
|---|---|---|---|
| ASK_ATTACH.conf | * | | ($Id_M$, $Id_{AP}$, $QoS_{negociated}$): |
| ATTACH.conf: | * | | ($Id_M$, $Id_{AP}$, $QoS_{negociated}$) |
| WAIT | * | | ($Id_M$, $Id_{AP}$) |
| ASK_RATTACH.req: | * | | ($Id_M$, $Id_{AP}$, liste_d'AP_possibles) |
| ASK_ATTACH.req | | * | ($Id_M$, $Id_{AP}$, $QoS_{expected}$) |
| ATTACH.req | | * | ($Id_M$, $Id_{AP}$, $QoS_{negociated}$) |
| ATTACH.req | | * | ($Id_M$, $Id_{AP}$, $QoS_{negociated}$) |
| ASK_RATTACH.conf | | * | ($Id_M$, New_$Id_{AP}$, Old_$Id_{AP}$) |
| LEAVE | | * | ($Id_M$, $Id_{AP}$) |
| OK | * | * | ($Id_M$, $Id_{APa}$, $Id_{APb}$) |
| MOD_QoS.req | * | * | ($Id_M$, $Id_{AP}$, $QoS_{proposed}$, Temps) |
| MOVE.req | * | * | ($Id_M$, $Id_{AP}$) |
| MOVE.conf | * | * | ($Id_M$, New_$Id_{AP}$, Old_$Id_{AP}$) |

## 6. Scenario description

The primitives that we defined in the last section are used to manage the access of the mobile stations to the wireless LAN via access points. Then we check theses primitives with many communications scenarios. Communications scenarios vary from simple to much complex situations. In this paragraph we describe one of the scenarios. This example is presented in Figure 6. M4 enter the wireless LAN and aim to connect to AP2 (Figure 5). AP2 is not able to offer connection to M4 with the requested quality of service level. It asks the load distribution server to find a new distribution to make possible the connection of M4 to AP2. After the computation of the load balancing algorithm, the load balancing server broadcasts the new distribution of mobile stations onto the access points. AP2 have to dissociate a mobile station M2. This one will be associated to AP2 which is able to give it the required quality of service level. Finally M4 and AP2 complete the connection procedure (Figure 7).

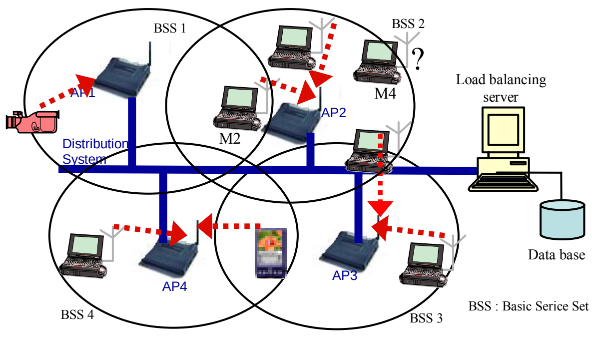


**Figure 5.** M4 asking for connection

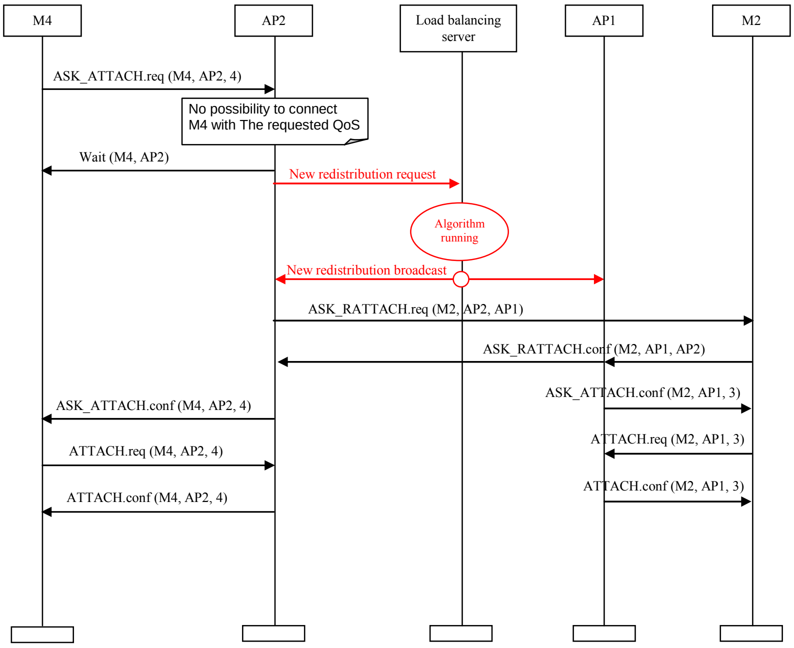


**Figure 6.** Example of communication scenario

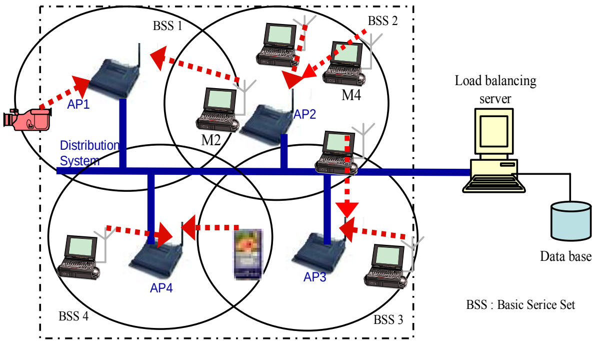


**Figure 7.** M4 connected to AP2

The scenarios that we have defined will be described and verified with the SDL and MSC languages in the following sections.

## 7. SDL protocol description

The SDL pattern is an efficient design language for the development of a communication system. It enables a formal description system by defining a static modular architecture and interactions between different blocks [7]. Systems in SDL language are structured into interconnected entities (system, block, process, and channel) where process system description provides dynamic behaviour for internal task execution. It is based on the model of Extended Finite State Machines (EFSMs) [8]. In its dynamic behaviour, each state is reached after asynchronous signal exchange between blocks [9].

New primitives and exchanges defined in our approach have been described and validated with SDL (Figs. 8 and 9). Figure 8 shows the SDL model of a mobile station. It represents exchanges between the management layer and the data base of the mobile station.

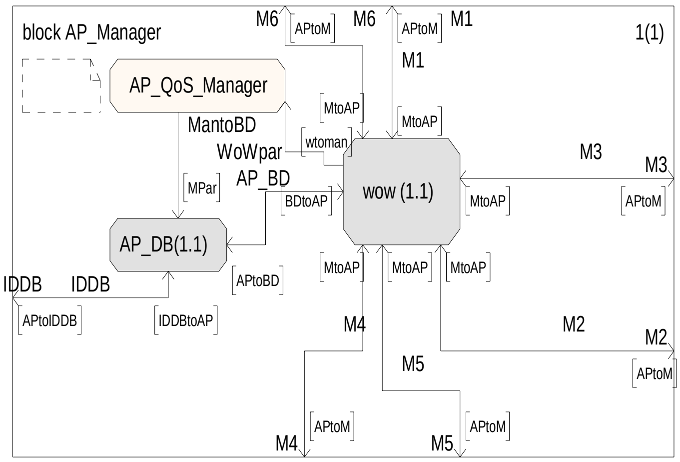


**Figure 7.** SDL model of a mobile station

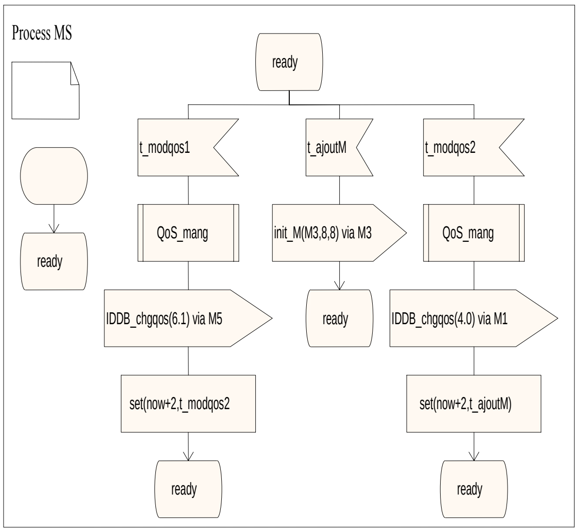


Figure 8. Example of SDL EFSM development

# 8. Conclusion

This paper addresses the problem of QoS management in the WLAN. It presents a protocol specification between mobile stations and access points to negotiate QoS requirements during the mobile station attachment. This protocol defines some new primitives related to the QoS management that must operate with the IEEE 802.11. The specification of these protocol primitives has been carried out.

The second part of this paper presents an SDL description of this protocol and it shows the behavior verification with MSC simulation.

This work has to be completed with an implementation of this approach in a simulation architecture using an appropriate tool such as Opnet or Network Simulator (NS). This helps to analyze the performances and helps to adjust the parameters of this protocol before the experimentation. Other parameters can be also used to characterize quality of service requirements of the mobile stations such as loss ratio or jitter.

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