Bandwidth management and fairness guarantee in wireless mesh network

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***Abstract*— The need of using an internet network any time and any place, requires the use of other solutions when the wired link doesn't exist. This yielded to the invention of the wireless mesh network that allows the broadening of the internet network cover.**

The wireless mesh network WMN based on the 802.11s standard is operating, even if it's a subject to many problems in some levels. For example there is the problem of congestion caused in principle by the aggressive packets flows. These flows occupy a big part of the resources compared to the others. Consequently, we will obtain an unfair sharing of the medium access.

Many mechanisms had been proposed as a solution to the unfairness problem, according to the previous work. From our side, we suggest in this work an algorithm that guarantees a fair sharing of the bandwidth for the different packets flows. The algorithm is based on the exchange of information between the nodes. These information concerns the desired rate of data by each node that are afterwards controlled thanks to the mechanism used in parallel: the token bucket.

***Index Terms*—WMN, fairness, bandwidth, token-bucket, rate.**

I. Introduction

The WMN technology favors the wireless equipment to connect side by side, in a dynamic way, instant and without a central hierarchy. It also allows the connection and the disconnection of new relay without the help of manual and boring configuration of the network. Thereby, this technology allows to the network to stand fault tolerance (if a node become inaccessible, the data flows can change the path easily and continue its routing). It is also relatively less expensive, and in terms of efficiency it can cover a large distance and answers to the temporary or permanently needs of a network connection.

In the infrastructure of the WMN, each Mesh Access Point MAP constitutes a relay which allows supposing that the Mesh Points MP are weakly mobile. This two components MAP and MP participate to the flows transfer from the client stations STA to the Mesh Portal Point MPP (i.e. the gateway) then to the internet via a wired infrastructure Fig. 1.

The architecture of the WMN allows to the multiple nodes to communicate between each other and form a multi-hops, mesh and wireless architecture. For that, a work team has focused their researches to restructure the standard 802.11 to 802.11s in order to support the paradigm of this architecture.

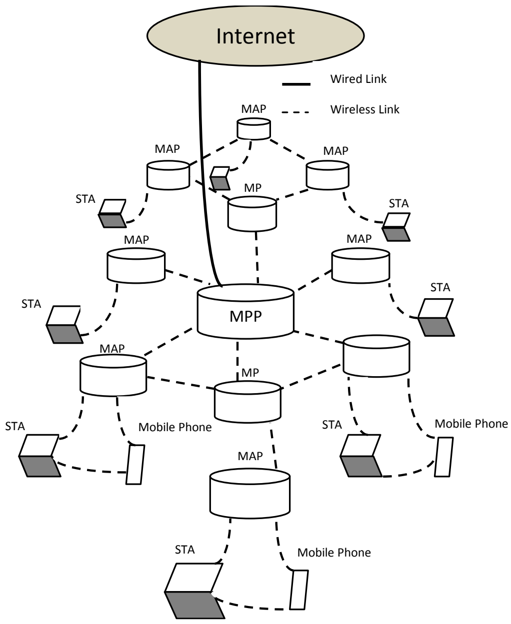

Fig. 1 Architecture of a wireless mesh network

The node in the wireless mesh network plays in the same time the role of a traffic generator and a medium for the packets flows coming from the other nodes. Consequently, the link layer of a node receive, on one hand, packets generated from the top-layers, and a lot of packets from the other flows of different nodes, on the other hand, the packets flows of top-layers are considered as aggressive flows, because the rate of their packets is higher than the rate of other flows.

This finding, allows to highlight a problematic related to the level of occupation of resources. This new concept of the network produces a concentration of flows to the gateway, which leads to the collusion between packets that accentuate more and more around this one. The collision exists also between the packets of flows coming from different nodes, and the aggressive flows descendant from the top-layers. Consequently, the occupation of resources for the different flows is unfair.

Inspired by the work [1], we propose a mechanism that guarantees a fair sharing of resources between the nodes in real time.

The mechanism is based on an exchange of control massages between the nodes in a periodic way. These messages contain information concerning the need of each node from the bandwidth. Once the node receives

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a control message, it saves all the information in a table and proceeds to the estimation of the maximal throughput it must benefits. This value will be used to control the rate of the outgoing packets using the token bucket mechanism.

II. THE UNFAIRNESS PROBLEM

The unfairness in computing network reflects the problem of the bandwidth sharing. In fact, a network can't guarantee, in every moment, the necessary rate of data for each node. In other way, it can't share the bandwidth in a fair manner between the data flows.

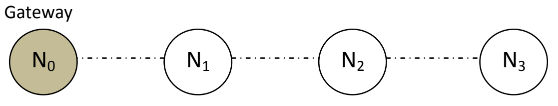

Fig. 2 Four nodes on a bus topology of a wireless mesh network

For a better comprehension of the problematic, we've done a simulation in Network Simulation NS2 with a bus topology of a wireless mesh network of four nodes based on the 802.11s standard Fig. 2. In this simulation, the nodes play a double role, it is in the same time, a generator of packets and a medium for other nodes flows. The nodes communicate between each other with the interfaces of 802.11 standard. The transmission area for each node is fixed on 250 meters. The necessary distance to separate the nodes from each other is fixed on 175 meters.

The scenario of the simulation is done in order that each node starts the transmission of packets to the gateway N0 with a time interval. The size of transmitted packets is 128 bytes with an inter-departure of 0.003 ms. To direct the packets to the gateway, we use the HWMP [8] as a routing protocol. The simulation take an end after 300 seconds, and the percentage of the received packets number by the gateway from each node is estimated in this moment Fig. 3.

We notice from the analyses of Fig. 3 that the gateway has received the packets coming from different nodes in an unfair way. We noticed that as long as the node is far from the gateway, this last receive a tiny quantity of packets coming from this node. However, in case of an adjacent node, the gateway receives an important quantity of packets. To find the principle cause of this result, we extracted the behavior of the bandwidth occupied by each node while the simulation Fig.4.

The analyses of Fig.4, allows to conclude that the unfair reception of packets by the gateway is the consequence of a bad occupation of the network bandwidth by different nodes. We observe, according to the throughput curves of each node flow in relation to time, that the far nodes from the gateway get a tiny throughput when the adjacent nodes have already started to send the packets. In this case, we consider that the adjacent nodes flows are the aggressive type since they occupy an important part of the resources in an excessive way.

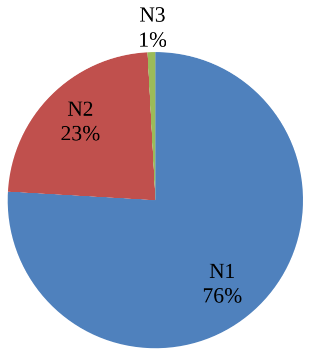

Fig. 3 The percentage of the number of packets received by gateway from each node

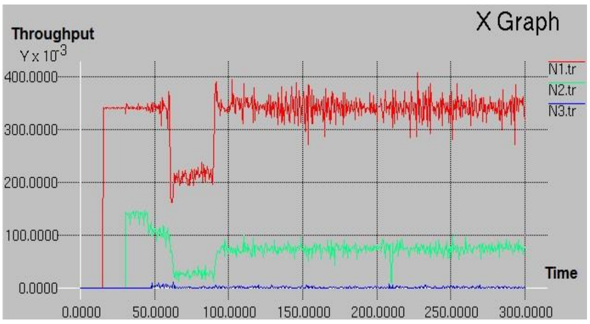

Fig. 4 The behavior of the bandwidth occupied by each node while the simulation.

A lot of researches have explained in a way the principal cause of the unfairness.

The work [2]'s author has discussed the role of the management mechanism of the queue in the unfairness problem. In a node, usually the queue is occupied in an aggressive manner by the packets descendant from the top-layer, which causes, the queue saturation. Consequently, the packets coming from the other nodes find themselves rejected and don't have access to the queue.

The researchers of the work [3] have mentioned also that among the reasons of the unfairness problem, it exist aggressive flows that have a high speed of transfer because of their proximity to the node. These flows are received frequently by the adjacent nodes to the gateway and occupy an important part of the node queue by preventing the other flows to accede it. The transmitted packets by the far nodes from the gateway do many hops and suffer many delays each time they cross a node.

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III. PREVIOUS WORK

To resolve the unfairness problem, many works were conducted in this meaning. In fact, some researchers have focused on the mechanisms that guarantee a fair sharing of the resources for different packets flows, coming from many nodes in a wireless mesh network. The goal is to ensure the routing of all the packets flows to their destination. From this works we specify some of them:

In the work [2], the researchers have proposed an algorithm that activates itself in each node and can guarantee a fair sharing of the queue for the different packet flows. The part of the queue that will be occupied by the flows is calculated being based on the bank of information in each node. These information concern the rate of flows which cross this node and vary dynamically according to the change of the flows rates. The mechanism ensures then the access of all the packets of different flows to the medium.

The researchers of the work [3] considered that it exist two types of packets flows, the aggressive and the non aggressive. With this principle, they have innovated a mechanism based on a variable named “drop probability” which allows to the node to decide either accept or reject the packets of aggressive flows. While each packets of aggressive flows rejection, it exist a value raise of the variable “drop probability”. This raise triggers a signal that prevents the aggressive packets access to the medium. Once the loss rate of non aggressive packets flows decreases, the “drop probability” decrements.

To avoid the collusion between the aggressive and non aggressive flows, a work team in the research [4] considered that in a wireless mesh network exist many gateways which the role is to carry the packets to the internet. They have shared these gateways in two types: the first ones manipulate the aggressive flows and the second manipulate the non aggressive flows.

The works in the article [5] cover the development of a routing protocol, which allows to change the path of a packet flow in case of a link congestion to the wireless mesh network. While each congestion of a node queue, the node send messages to the adjacent nodes in order to change the path of their packets flows, if they use the congested node as a medium.

The researchers of the article [6] have reserved some resources by periods, for the transfer of each node packets in a fair manner. The mechanism uses the parameter TXOP of the 802.11e standard, in order to allocate a transmission time for each node proportional to the TXOP and which depends on the number of clients stations related to this node.

In the work [7], the mechanism allows to give the smallest values of CWmin and CXmax for the adjacent node to the gateway, and the highest values to the far nodes from the gateway. The aim is to minimize the probability of collusion between the nodes flows and to allow the fairness at the resources allocation.

IV. FAIRNESS GUARANTEE FOR MEDIUM ACCESS FGMA

The FGMA is an algorithm that we implemented in a wireless mesh network node. The interest of this mechanism is to settle in a continuous time, the throughput of a node flow compared on one hand, to the throughput that it desires, on another hand, the throughput that the other network nodes desires to receive. The regulation of the packet rate will be done thanks to the token bucket mechanism.

A. The token bucket

The algorithm of the token bucket permits to control the flow throughput produced by a node in a network. The control is done in a manner to settle directly the throughput in bits per second Fig. 5.

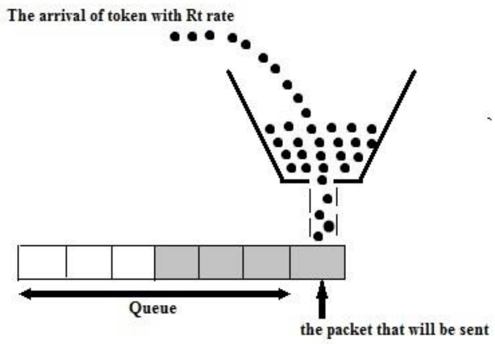

Fig. 5 token bucket mechanism

The token bucket is built in this way:

- We consider a leaky bucket from the bottom that contains tokens and each token present one bit.
- The size of the bucket presents the quantity of tokens which can be stocked, measured by bytes.
- The bucket is full of tokens with a constant rate $\mathbf{R_t}$.
- The transmission of a packet is accompanied with a reduction of tokens from the bucket. The number of tokens excluded is equivalent to the size of packets by bit.
- When a packet arrives, if there is not enough tokens in the bucket left, it must wait in the queue until the bucket is full. If the queue is congested, the packet is in excess.

Our protocol allows putting in each period t, the value of benefit rate by a node to the $\mathbf{R_t}$ variable of the token bucket mechanism. This last will be including in the link layer of each node.

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B. The FGMA mechanism

The FGMA algorithm is executed periodically in each node in order that this last can vary its own data rate, according to the requirements of the network in a moment **t**.

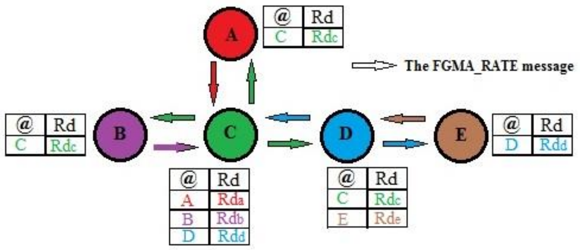

Fig. 6 The exchange of FGMA_RATE messages

The algorithm work in a moment t this way:

- All the network nodes will send a message named **FGMA_RATE** by broadcast to the adjacent nodes in one hop.
- The **FGMA_RATE** contain two necessary information: the MAC address of the message generator node and the packet rate desired $\mathbf{R_d}$.
- Each node will receive many **FGMA_RATE** messages, and while each reception the node will stock the content of this message in a table named "rate table" made of two columns: MAC address and desired rate Fig. 6.
- In each storage of new information in the rate table, the node will calculate the rate that it must benefits $\mathbf{R_b}$ from the network bandwidth.

The figure Fig. 7 sums up the FGMA mechanism progress.

Program: This mechanism allows each node to have an accurate throughput and to guarantee the network fairness

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Input:

- R_{d_i}: all desired rate by the adjacent nodes in a single hop at time **t**, and that are saved in the node **x** table of rates (i є {0,1.2…,n})
- R_g : the overall rate of the network

Output:

- R_{b_x} : the rate that will be benefited by a node **x** from the network bandwidth at time **t**

Begin

When we receive a FGMA_RATE message, the node performs the following actions:

- Extract from the FGMA_RATE messages the sender's address **@** and the rate it desired $\mathbf{R_d}$.
- Save the desired rate $\mathbf{R_d}$ and the sender address **@** in the rates table.
- Calculate the rate that will be benefited $\mathbf{R_b}$ by the node **x** from the network bandwidth.
- Affect the rate benefited $\mathbf{R_b}$ to the rate of token $\mathbf{R_t}$ at the token bucket mechanism.

End

Fig. 7 The FGMA algorithm mechanism

C. Benefit rate formula

The rate value which the node benefit is calculated based on the rate desired by this node and also the rates table recording. The comprehension of the benefit rate $\mathbf{R_b}$ formula requires the following variables definition:

- $\mathbf{R_{d_x}}$: The desired rate by a node **x** in a moment t.
- $\mathbf{R_{b_x}}$: The node x benefit rate in a moment **t**.
- $\mathbf{R_g}$: the network global rate.
- $\mathbf{R_{th}}$:the network theoretical rate.

$$\mathbf{R_g = \beta * R_{th}} \quad (\boldsymbol{\beta \sim= 0.7})$$

- $\mathbf{R_e}$: Evenly shared rate
- $\mathbf{R_e = R_g/n}$ (n: number of nodes in the network)
- $\mathbf{R_r}$: the residual rate

$$\mathbf{R_r = \sum_{i=1}^{p} R_e - R_{d_i}}$$

  - ✓ In case of $\mathbf{R_e} > \mathbf{R_{d_i}}$
  - ✓ p: the number of nodes when $\mathbf{R_e} > \mathbf{R_{d_i}}$
- $\mathbf{R_{min}}$: the minimum rate benefited by a node in the network.

We will present the rate benefited by a node x in this way:

1) If $\mathbf{R_{d_x} < R_{min}}$

$$\mathbf{R_{b_x} = R_{min}}$$

2) If $\mathbf{R_{min} < R_{d_x} < R_e}$

$$\mathbf{R_{b_x} = R_{d_x}}$$

3) If $\mathbf{R_{d_x} > R_e}$

We perform the following calculation:

$$\mathbf{R_{b_x} = R_e + R_{a_x}}$$

✓ $\boldsymbol{R_{a_x}}$: The quantity of rate which we can add to the node that ask for more $\mathbf{R_e}$.

$$\mathbf{R_{a_x} = \frac{R_r * P_x}{100}}$$

✓ $\mathbf{P_x}$: the percentage of the residual rate benefited by the node **x** when $\mathbf{R_{d_x} > R_e}$

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$$P_x = \frac{(R_{d_x} - R_e) * 100}{\sum_{i=1}^{k} R_{d_i} - R_e}$$

- ✓ **k**: the number of nodes when $R_{d_i} > R_e$

From b) and c):

$$R_{a_x} = \frac{R_r * (R_{d_x} - R_e)}{\sum_{i=1}^{k}(R_{d_i} - R_e)}$$

The final formula which allows to calculate the rate benefited by a node x when $R_{d_x} > R_e$ is as follows:

From a) and d):

$$R_{b_x} = R_e + \frac{R_r * (R_{d_x} - R_e)}{\sum_{i=1}^{k}(R_{d_i} - R_e)}$$

V. THE FGMA SIMULATION:

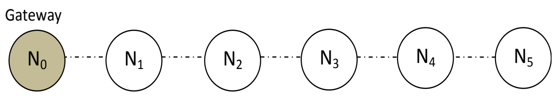

Fig. 8 Six nodes on a bus topology of a wireless mesh network

To show the efficiency of our mechanism, we will realize the same previous simulation adopting six nodes in a bus topology with the FGMA algorithm Fig.8. We present in the Fig.9 the new result of packets number percentage received by the gateway from each node. In the Fig.10, appears the behavior of the bandwidth occupied by each node during the simulation.

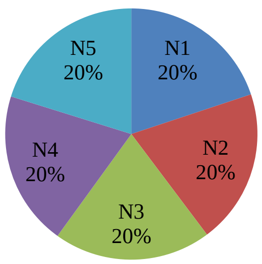

Fig. 9 The percentage of the number of packets received by gateway from each node with the FGMA algorithm

From the analysis of the figure Fig.9, we can see that the FGMA algorithm has a positive impact on the network fairness. All the nodes at the end of the simulation sent the same quantity of packets to the gateway. And from the Fig.10 we can explain the result of Fig.9: is that the FGMA allows to the network nodes to obtain equal rates during all the time of simulation, and consequently, they send approximately the same number of packets.

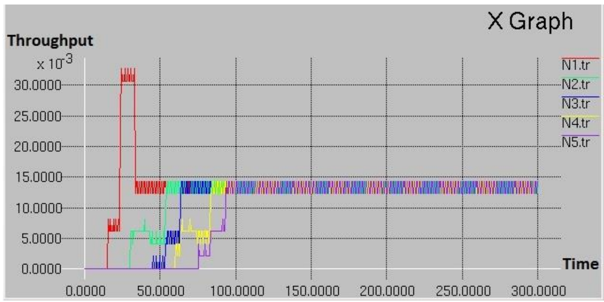

Fig.10 The behavior of the bandwidth occupied by each node with the FGMA algorithm while the simulation

We explain this positive result, by the fact that the FGMA limits the rate of each node packets in order to not exceed a maximum rate. Moreover, the aggressive flows can't occupy a bandwidth over the non-aggressive flows. On the other side, the majority of non-aggressive flows benefit from the desired bandwidth, and the aggressive flows benefit an authorized maximum rate in order to not unbalance the network fairness.

VI. CONCLUSION

This work permit to us to extricate some conclusions.

The protocols of the medium access management in the 802.11 standard are not efficient. The first simulation shows that these protocols didn't guarantee in each moment t, the necessary throughput for the different flows. We deduced that the far nodes from the gateway flows are exposed to a severe competition from the close nodes from the gateway flows. Consequently, we obtain unfair resources reservation.

To solve the unfairness problem, we simply control each packet flow rates coming from different nodes, and also do not have resources reservation by a packet flow at the detriment of another. This concept was demonstrated by the FGMA algorithm.

REFERENCES

[1] E.Horlait, M.Bouyer. Universite Pierre et Marie Curie Laboratoire LIP6. CLEP (Controlled Load Ethernet Protocol): Bandwidth Management and Reservation Protocol for Shared Media [in line]. available on: <https://tools.ietf.org/html/draft-horlait-clep-00> (consulted 01.02.2015)

[2] Nagesh S. Nandiraju, Deepti S. Nandiraju, Dave Cavalcanti, Dharma P. Agrawal. A Novel Queue Management Mechanism for IEEE 802.11s based Mesh Networks, 10-12 April 2006, Phoenix, International Performance Computing and Communications Conference IPCCC, 7 pp. – 168, 1-4244-0198-4.

[3] Nagesh S. Nandiraju, Deepti S. Nandiraju, Lakshmi Santhanam, Dharma P. Agrawal. A Cache Based Traffic

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Regulator for Improving Performance in IEEE 802.11s based Mesh Networks, 9-11 Jan 2007, Long Beach. CA, Radio and Wireless Symposium, pp 293 – 296, 1-4244-0445-2.

[4] Harish Kongara, Yogesh R Kondareddy, Prathima Agrawal. Fairness and Gateway Classification Algorithm (GCA) in Multihop Wireless Mesh Networks, 15-17 March 2009, Tullahoma, 41st Southeastern Symposium on System Theory (SSST), pages 77 – 81, 978-1-4244-3325-4.

[5] Malik Mehroze, Khalid Usmani, Faraz Ahsan, Sohail Asghar. Fairness Based Dynamic Routing Technique (FsBDRT) in Wireless Mesh Network, Research Journal of Information Technology. V5, December 2013, pages 97-103.

[6] Jorge L S Peixoto, Marcial P Fernandez, Luis F de Moraes. Improving Fairness in Wireless Mesh Networks, 29 February 2012, Saint Gilles. Reunion, The Eleventh International Conference on Networks, Pages: 175-180, 978-1-61208-183-0.

[7] Salim Nahle, Naceur Malouch. Fairness Enhancement in Wireless Mesh Networks, 10-13 December 2007, Columbia University New York, 3rd International Conference on emerging Networking EXperiments and Technologies (CoNEXT), Article No 30, 978-1-59593-770-4.

[8] The Working Group for WLAN Standards of the IEEE. HWMP Specification [online]. Available on: https://mentor.ieee.org/802.11/public/06/11-06-1778-01-000s-hwmp-specification.doc . 2006-11.

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