A Cross-layer Framework for IEEE 802.11s-operated Wireless Mesh Sensor Networks

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Abstract

This paper describes a new cross-layer architecture to compute the throughput performance of an IEEE 802.11s architecture. We present a mathematical model that combines parameters from network and MAC layers. We study the throughput routes and stability of forwarding queues. We focus on a wireless mesh network with static nodes in mesh backhaul and mobile mesh clients. We suppose that we have one route between any two nodes in the network and we study the impact of transmitting probability and the bound on attempts on throughput performance, we also study the impact of hop count and number of connections on the system performance.

Keywords:
wireless mesh network; Cross-layer Architecture; Stability; Throughput; Retransmission; Queuing Theory.

1. Introduction

Today a new technology referred to as wireless mesh networking has the potential to considerably influence how we communicate. Although derived from military research into mobile networks, the emergence of wireless mesh networking has its greatest potential in the commercial marketplace. The single hop approach is replaced by a multi-hop mechanism.

Wireless mesh network (WMNs) [1] are dynamically self-organized and self-configured. They are comprised of two types of nodes: mesh routers and mesh clients, the standardization of wireless mesh network in IEEE 802.11s being worked on. The goal of the IEEE 802.11s is the development of an extensible standard for wireless mesh network based on IEEE 802.11. One of the important contributions of the wireless mesh network is to propose cross-layer architecture to calculate the throughput performance. The medium access control (MAC) is an important technique that enables the successful operation of the network. One fundamental task of the MAC protocol is to avoid collisions so that two interfering nodes do not transmit at the same time. Many works have been proposed to develop the performance of MAC protocols. Many of these approaches have been based on the target IEEE 802.11. In [2, 3], the researches focus on Ad hoc routing protocols under the assumption that some underline MAC protocols can provide good services to higher layers. In [4, 5], they consider two separate queues for these two types and do a weighted fair queuing (WFQ). In [6], the authors propose an extending the coverage of UMTS using an Ad hoc network to characterize the conditions of stability and the throughput. In [7], they propose a cross-layer architecture that supports service differentiation in wireless sensor networks.

The main contributions of this paper are providing a framework for cross-layer study of stability-throughput performance of mesh network. At each node, this cross-layer architecture has flexibility for managing worded packets and its own packets differently. The stability, in this paper, takes into account the possibility of limed number of transmission of a packet after which it is dropped for system reliability reasons.

The rest of this paper is structured as follows. Section II presents the overview on mesh network. In section III, we present the network model. The network stability and performance are characterized by using the rate balance equation in section IV. The validation of analytical results and discussion are introduced in section V. the last section summarizes the work done and presents some future works.

2. Overview on Mesh Networks

A wireless mesh network is a set of fixed routers connected with each other by a wireless distribution system to serve a set of mobile mesh clients. In this section, we present an overview on mesh network.

2.1 Mesh network architecture

Fig. 1 shows an IEEE 802.11s based wireless mesh network. It consists of a collection of hybrid devices communicating using several non-overlapping channels. There are, in general, four device classes in a WLAN mesh network, namely.

The mesh point (MP) establishes peer links with MP/MAP neighbors, full participant in WLAN Mesh services MP is conceived to participate only in 1-hop communications with immediate neighbors and implements no routing capability. It is clear that a MP does not need to associate to any AP to get connected to the mesh network. Moreover, a MP has the capability to generate its own traffic, is able to forward packets and to dynamically learn the topology of the whole network.

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A mesh access point (MAP) has functionality of a MP, collocated with AP which provides Basic Service Set (BSS) services to support communication with the end-users. In other words, a MAP is the network entity that provides to end-users access to the available services. To further improve the flexibility of mesh networking, a MAP is usually equipped with multiple wireless.

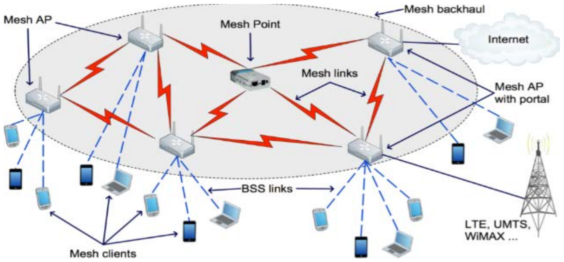

Fig. 1 A typical exemple of IEEE 802.11s-operated Mesh Networks. A Mesh Point (MP) just forwards mesh traffic, a Mesh Access Point (MAP) allows Mesh Clients (MC) to associate to it and to access offred services. A MAP may also play the role of portal to enter/exit the mesh.

Interfaces built on either the same or different wireless access technologies. Compared to a conventional wireless router, a MAP can achieve the same coverage with much lower transmission power through multi-hop communications. The WMN backbone can be built using various types of radio technology, in addition to the commonly used IEEE 802.11 standards. The MAPs form a mesh of self-configuring, self-topology learning and self- healing links among themselves.

The mesh client (MC) represents the end-user which communicates with another MC or another mesh entity. The MCs are usually equipped with one type of radio device. Moreover, the requirements on end-user devices are increased, since in, they have to perform additional functions such as routing and self-configuration.

2.2 Bandwidth enhancement

A mesh network is multi-hop network based on an infrastructure. It provides wireless access with high throughput. It can eliminate low coverage and non-covered areas to support new applications of high throughput. These networks are primary used to provide internet access with high throughput for all connected users. The multimedia services such as voice over IP and video will provide to all users.

2.3 Routing and Traffic balancing

The routing in 802.11s is particularly based on MANET protocols, among protocols considered by mesh network:

- Hybrid wireless mesh protocol (HWMP) [9]: this protocol combines two different modes, the first is called radio metric ad hoc on-demand vector (RM-AODV) which is demand routing. The second one is a tree based routing.
- Radio-Aware optimized link state routing (RA-OLSR): this protocol is based on OLSR, it is suitable in the case of low mobility.

There routing protocols must support unicast and broadcast/multicast communications. For broadcast communications, a mechanism based on the sequence numbers is used in RM-AODV and an optimized broadcast tree is generated by RA-OLSR to eliminated loops.

2.4 Mesh Deterministic Access

The available resources should be efficiently allocated in mesh network. In this part, we will discuss mechanisms to improve the MAC layer:

- Enhanced distributed channel access (EDCA): the improvement of QoS at the MAC layer introduced by 802.11e is used as a base in 802.11s. EDCA offers four categories of access: voice, video, best-effort and background.
- Mesh deterministic access (MDA): this method of access allows the mesh clients to access the channel at a given time. It is based on a reservation protocol that uses a shack hand between transmitter/receiver to establish MDA opportunities (MDAOPs).
- Intra-mesh congestion control (IMCC): is a management control mechanism implemented at each node that monitors local use channel. If congestion is detected the node informs its neighbours, each node that received a congestion message should adjust its throughput.
- Common channel framework (CCF): this mechanism allows the negotiation channel to exchange data between two nodes. It can be used in multi-channel networks.
- Automatic power save delivery (APSD): is energy saving mechanism in which the stations count relying on MP to save their energies. In mesh network, the MAP must remain without interruption then it must have necessarily energy saving mechanism on the contrary of MP.

The MAC services are based on synchronization which is also used to avoid collision of control trams.

3. Network model

In this section, we provide the assumptions underlying this study and introduce appropriate notations. We describe also the operation of the network and quantities that determine the overall performance.

3.1 Assumption and definitions

We consider a wide geographical area served by a WMN. Let A and M respectively, be the set of mesh access points and the set of mesh points. Without any loss of generality, we consider through this paper that mesh links use a common channel, we denote it ML. The set of end-users associated to MAP is denoted $U(a)$. We assume that a perfect channels reuse is used, then each MAP is serving its MCs on a separate channel. This way, there is no inter-cell interferences, BSS communications are only impacted by intra-cell concurrent transmissions. Moreover, this latter channel does not overlap with ML. Actually a couple of source s and destination d are not in the same cell, then their communications should be relayed by intermediate MAPs/MPs. We denote the set of MAPs/MPs relaying packets originating from s by $R_{s,d}$ (s and d not included). We assume that mesh clients are saturated, i.e., they always have packets ready to be transmitted.

We denote by $N^a(i)$ and $N^b(i)$, respectively, the set of neighboring nodes (MAP, MP or MC) of node i communicating, respectively, with IEEE 802.11a and IEEE 80.2.11b/g. Note that $N^a(i) \subset A \cup M$ and $N^b(i) \subset C \cup A \cup M$. For each MAP/MP i, we assume the following:

- A single channel: Nodes use the same frequency for transmitting with an omnidirectional antenna. A node MAP/MP j receives successfully a packet from a node MAP/MP i if and only if there is no interference at the node MAP/MP j due to another transmission on the same channel, that is, if there is no transmission from any node of the set $N^a(j) \cup j$ and any node of the set $N^b(i)$. A node cannot receive and transmit at the same time.
- Two types of queues: Two queues are associated with each node. The first one is F_i which carries all the packets originated from a given source and destined to a given destination. The second is Q_i which carries the proper packets of the node MAP/MP i. We assume that each node MAP/MP i has an infinite capacity of storage for the two queues. When F_i has a packet to be sent, the node chooses to send it from F_i with probability f_i and from Q_i with a probability$1 - f_i$.
- Saturated network: Each node has always packets to be sent from queue Q_i and F_i, however they can be empty. Consequently, the network is considered saturated, and thus it depends on the channel access mechanism. This assumption is suitable to determine the limit operation of the network.

3.2 Mesh Backhaul Network

The mesh backhaul network (MBN): is wireless distribution system (WDS), this fixed part of mesh network based on the 802.11 standard, it is composed of MAPs, MPs and mesh gateways connect with each other by wireless links (mesh links) to construct a mesh WLAN. For each node MAP/MP i of this network we have:

A. Network layer

The network layer of each node MAP/MP i handles the two queues F_i and Q_i using the WFQ scheme. In this paper, we assume that nodes form a static network where routes between any source s and destination d are invariant. All nodes act as routers and forward packets for each other and we denote by $R_{s,d}$ the set of nodes MAP/MP i between a source s and destination d (s and d not included). We present below the parameters and notations used in this paper:

TABLE I. MAIN NOTATIONS USED IN THE PAPER

f_i	Probability at which a MAP/MP forwards a packet to its final destination or to another MAP/MP i.
$\pi_{i,s,d}$	The probability that the queue F_i has a packet at the first position ready to be forwarded for the path $R_{s,d}$ in the beginning of each cycle.
π_i	The probability that the queue F_i has at least one packet to be forwarded. We have $\pi_i = \sum_{s,d} \pi_{i,s,d}$
$K_{i,s,d}$	The maximum number of transmission allowed by a node i per packet of the path $R_{s,d}$.
$P_{i,d}$	Probability that node i transmits its own packet to node d.
$L_{i,s,d}$	The expected number of attempts till success or definitive drop from node i on route $R_{s,d}$.
$\overline{L_i}$	The expected number of attempts till success or definitive drop from node i.

B. MAC layer

We assume a channel access mechanism only based on a probability to access the network. When a node MAP/MP i has a packet to transmit, it accesses the channel with a probability P_i For example, in IEEE 802.11 DCF, the attempt probability is given by [11]:

$$P = \frac{2(1 - 2P_c)}{(1 - 2P_c)(CW_{min} + 1) + P_c CW_{min}(1 - (2P_c)^m)}$$

Where P_c is the collision probability given that a transmission attempts is made, and $m = \log_2\left(\frac{CW_{max}}{CW_{min}}\right)$ is the maximum of back off stage.

C. PHY layer

The 802.11s standard use whenever possible the different mechanisms defined in other 802.11 standards. For example, it uses the 11i in security and 11e to define QoS mechanisms. Indeed, it is possible to use any layer PHY 802.11 a/b/g/n.

D. Cross-layer architecture

Figure 3 is the cross-layer representation of our model for each node MAP/MP i. Attempting to access the channel begins by choosing the queue from which a packet must be selected and then this packet is moved from the corresponding queue from the network layer to the MAC layer where it will be transmitted and retransmitted, if needed, until its success or drop. When a packet is in the MAC layer, it is itself attempted successively until it is removed from the node MAP/MP i.

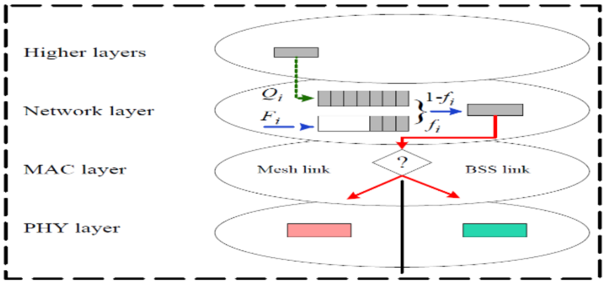

Fig.2 Cross-layer architecture of the IEEE 802.11s-operated mesh network.

At any time slot there are four kinds of flows crossing a MAP i.

- Own flow: Packets generated by mesh client nodes in the direct range of MAP i.
- Inner flow: Packets arrived from the neighbouring MAPs/MPs.
- Outer flow: Packets forwarded to other MAPs/MPs.
- Delivered flow: This represents all packets forwarded to final destination in the covered area of MAP/MP i.

Here, each MAP i handle a queue F_i that carries packets to be forwarded to their destination. Fig. 3 shows the queuing network representation of our system.

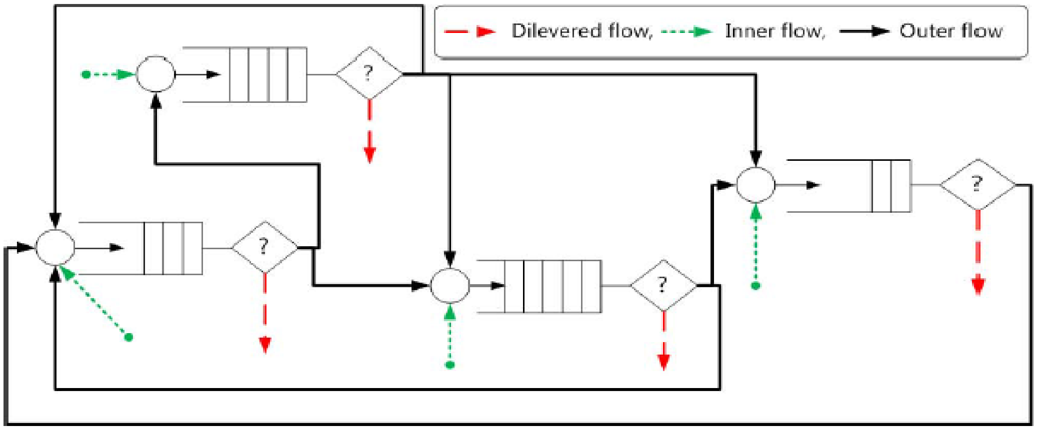

Fig. 3 Associated queueing network of the IEEE 802.11s-operated mesh network.

E. Calculation of the average number of attempts per packet

Our main objective in this part is to define the average number of attempts per packet over all possible paths. Each node owns four main parameters $P_i, K_{i,s,d}$ and f_i that can be managed and set in such a way that each node can maintain stability, or the throughput on a path can be optimized.

Let $J_{i,s,d}$ the neighbor node of MAP/MP i in the set $R_{s,d}$, the probability that a transmission from node MAP/MP i on route from node s to node d is successful is,

$$P_{i,s,d} = \prod_{j \in J_{i,s,d} \cup N(J_{i,s,d}) \setminus i} (1 - P_j)$$

The expected number of attempts till success or dropping packet from MAP/MP i on route $R_{s,d}$ is,

$$L_{i,s,d} = \frac{1-(1-P_{i,s,d})^{K_{i,s,d}}}{P_{i,s,d}}$$

Then the average number of attempts per packet $L_i$over all possible paths is,

$$\overline{L_i} = \sum_{s,d:i\epsilon R_{s,d}} f_i\pi_{i,s,d}L_{i,s,d} + \sum_d (1-f_i\pi_i)P_{i,d}L_{i,s,d}$$

3.3 Mesh Basic Service Set sub-Network

The mesh basic service set-network (MBSSN) is a part of the mesh network that contains a set of mobile mesh clients connected to a fixed MAP by a wireless link (BSS link) to construct a structure BSS (basic service set). Our objective in this section is to calculate the own flow and inner flow that comes from the BSS link to MAP in the structure BSS. For that we use Bianchi [2000] model.

Let S be the normalized system throughput [8], defined as the fraction of time the channel is used to successfully transmit payload bits. To compute S, let us analyze what can happen in a randomly chosen slot time. Let P_{tr} be the probability that there is at least one transmission in the considered slot time. Since stations contend on the channel, and each transmits with probability

$$P_{tr} = 1 - (1-\tau)^n$$

The probability P_s that a transmission occurring on the channel is successful is given by the probability that exactly one station transmits on the channel, conditioned on the fact that at least one station transmits, i.e.,

$$P_s = \frac{n\tau(1-\tau)^{n-1}}{P_{tr}} = \frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n}$$

According to Bianchi [2000], the Saturation throughput S is:

$$S = \frac{\text{E [payload information transmitted in a slot time]}}{\text{E[lenght of a slot time]}}$$

Being E[P] the average packet payload size, the average amount of payload information successfully transmitted in a slot time is $P_{tr}P_sE[P]$. Hence, the above equation becomes

$$S = \frac{P_{tr}P_sE[P]}{(1-P_{tr})\sigma + P_{tr}P_s T_s + P_{tr}(1-P_s)T_c}$$

T_s is the average time the channel is sensed busy because of a successful transmission, and T_c is the average time the channel is sensed busy by each station during a collision. σ is the duration of an empty slot time.

We are now able to express the own flow d'which represents the packets generated by mesh client in the direct range of MAP i. Let n the number of BSS nodes including the mesh access point, then :

$$d' = \frac{n.P_{tr}.P_s.E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s T_s + P_{tr}(1-P_s)T_c\right]}$$

For MAP, the inner flow which presents the packets comes from the BSS link is given by the following equation:

$$\alpha' = \frac{P_{tr}.P_s.E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s T_s + P_{tr}(1-P_s)T_c\right]}$$

4. Stability of the forwarding queues

In this section, we use the rate balance equations to write the departure rate from each node i and the throughput between a couple of node.

A. The departure rate

The probability that a packet is removed from a node i by a successful transmission or a drop is the departure rate. We denote it by d_i. The departure rate concerning only the packets sent on the path $R_{s,d}$ is denoted by $d_{i,s,d}$ which is given by the following proposition:

Proposition 1: for any node i, s and d, the long term average rate of departure of packets from node i on route from node s to node d is

$$d_{i,s,d} = \frac{\pi_{i,s,d}P_if_i}{\overline{L_i}} + \frac{n.P_{tr}.P_s.E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s T_s + P_{tr}(1-P_s)T_c\right]}$$

Then, the total departure rate is given by

$$d_i = \sum_{s,d:R_{s,d}} \frac{\pi_{i,s,d}P_if_i}{\overline{L_i}} + \frac{n.P_{tr}.P_s.E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s T_s + P_{tr}(1-P_s)T_c\right]} = \pi_if_i\frac{P_i}{\overline{L_i}} + \frac{n.P_{tr}.P_s.E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s T_s + P_{tr}(1-P_s)T_c\right]}$$

Remark that when the node i is the source, the above equation becomes

$$d_s = \pi_{i,s,d}f_i + \frac{n.P_{tr}.P_s.E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s T_s + P_{tr}(1-P_s)T_c\right]}$$

B. The arrival rate

The probability that a packet arrives to the node i is the arrival rate on an intermediate node, is denoted by α_i. When this rate concerns only packets sent on the path $R_{s,d}$, we denoted it by $\alpha_{i,s,d}$ which is given by the following proposition:

Proposition 2: for any node i, s and d, the long term average rate of arrival of packets into $R_{s,d}$ is

$$\alpha_{i,s,d} = (1 - \pi_s f_s).\, P_{s,d}.\frac{P_s}{\overline{L_s}}.\left[(1-(1 - P_{s,s,d})^{K_{i,s,d}}.\prod_{k\in R_{i,s,d}\setminus i}(1-(1-P_{k,s,d})^{K_{k,s,d}})\right] + \frac{P_{tr}.\, P_s.\, E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s\, T_s + P_{tr}(1-P_s)T_c\right]}$$

Remark that when the node i is the destination of a path $R_{s,d}$, then $\alpha_{d,s,d}$ represents the average throughput of a connection from s to d. Then the global arrival rate is

$$\alpha_i = \sum\nolimits_{s,d:i\in R_{s,d}} \alpha_{i,s,d} = \sum\nolimits_{s,d:i\in R_{s,d}}\left((1 - \pi_s f_s).\, P_{s,d}.\frac{P_s}{\overline{L_s}}.\left[(1-(1 - P_{s,s,d})^{K_{i,s,d}}.\prod_{k\in R_{i,s,d}\setminus i}(1-(1-P_{k,s,d})^{K_{k,s,d}})\right]\right) + \frac{P_{tr}.\, P_s.\, E[P]}{(n+1)\left[(1-P_{tr})\sigma + P_{tr}P_s\, T_s + P_{tr}(1-P_s)T_c\right]}$$

C. The rate balance equations

The mesh network is stable if the backhaul mesh and different structures BSS are stable. Our model uses Bianchi[2000] model to calculate the throughput in the BSS, this model computes the saturation throughput who is the payload information that the system can support in the stable conditions. Then network BSS structures are stable. It remains to determine the stability conditions of the mesh backhaul part. The mesh backhaul is stable if and only if all MAPs/MPs are stable. A MAP/MP is stable if and only if queue F_i is stable.

By the standard definition of stability, queue F_i is stable while its corresponding departure rate is greater or equal than the arrival rate into it. We consider the extreme case where we have strict equality. For each nodes MAP/MP i, s and d, we get $d_{i,s,d} = \alpha_{i,s,d}$. We obtain the following system:

$$\frac{\pi_{i,s,d}P_i f_i}{\overline{L_i}} = (1 - \pi_s f_s).\, P_{s,d}.\frac{P_s}{\overline{L_s}}.\left[(1-(1 - P_{s,s,d})^{K_{i,s,d}}.\prod_{k\in R_{i,s,d}\setminus i}(1-(1-P_{k,s,d})^{K_{k,s,d}})\right]$$

The conditions that verified the above equation is given by the following proposition,

Proposition 3: If all the queues in the network are stable, then for each i, s and d such that $i \in R_{s,d}$ [5]:

$$\frac{\pi_{i,s,d}P_i f_i}{\overline{L_i}} = (1 - \pi_s f_s).\, P_{s,d}.\frac{P_s}{\overline{L_s}}.\left[(1-(1 - P_{s,s,d})^{K_{i,s,d}}.\prod_{k\in R_{i,s,d}\setminus i}(1-(1-P_{k,s,d})^{K_{k,s,d}})\right]$$

For all i, s and d. Let

$$\begin{cases} y_i = 1 - \pi_i f_i \\ z_{i,s,d} = \pi_{i,s,d} f_i \end{cases}$$

Thus $y_i = 1 - \sum_{s,d:i\in R_{s,d}} z_{i,s,d}$, Then rate balance equation becomes (E):

$$\sum_{d:i\in R_{s,d}} z_{i,s,d} = \frac{y_s\left(\sum_{s',d'} z_{i,s',d'}L_{i,s',d'} + \sum_{d''} y_i P_{i,d''}\, L_{i,i,d''}\right)w_{s,i}}{\left(\sum_{s',d'} z_{s,s',d'}L_{s,s',d'} + \sum_{d''} y_s P_{i,d''}\, L_{s,s,d''}\right)}$$

Where

$$w_{s,i} = \sum_{d:i\in R_{s,d}} \frac{P_{s,d}P_s}{P_i} \prod_{k\in R_{i,s,d}\cup s\setminus i} (1-(1-P_{k,s,d})^{K_{k,s,d}})$$

D. Special cases

The system of above equations is not always linear. There are some cases where this system becomes linear. It can be obtained when for each node MAP/MP i, we have that $\overline{L_i^r}$ is independent from y_i and $z_{i,s,d}$. A symmetric network $n_i = n$, $P_i = P$ and $K_{i,s,d} = K$ is example where the rate balance is linear. In the asymmetric network when each node uses the same neighbor as a next hop to forward all its packets the condition is satisfied. Consequently, the system from (E) can be written as:

$$1 - y_i = \sum_s y_s \overline{w}_{s,i}$$

Where

$$\overline{w}_{s,i} = \sum_{d:i\in R_{s,d}} \frac{P_{s,d} P_s P_{s,s,d} L_{i,s,d}}{P_i} \prod_{k\in R_{i,s,d}\cup s\backslash i} (1 - (1 - P_{k,s,d})^{K_{k,s,d}})$$

The system of above equation can be written in a matrix form as following and resolved easily:

$$y(I + \overline{W}) = 1$$

5. Numerical RESULTS

We deploy a wireless mesh network with 5 static nodes in mesh backhaul and 12 mobile mesh clients. In this section, we consider that we have only one route between any two nodes. Three connections are established a, b and c, figure 4, these connections choose the shortest-path in terms of hops to route their packets. We choose the parameters $K_{i,s,d} \equiv K$, $f_i \equiv f$ and $P_i \equiv P$ in a manner of enabling stability. In this work, we have taken the following scenario: for mesh backhaul, the node is modeled using $f = 0.5$ with the transmission probability P_i has been varied. In BSS structure, we assume that there is no collision, then the probability of success $P_s = 1$ and the probability that there is at least one transmission in the considered slot time $P_{tr} = 1$, we can also simplify the expression of payload information by assuming that it has a constant size $E[P] = P$.

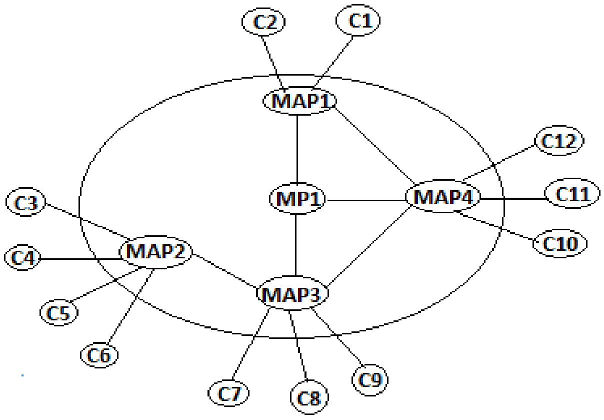

Fig. 4 wireless mesh network

Connection a: C1-MAP1-MAP4-C11
Connection b: C4-MAP2-MAP3-MAP4-C10
Connection c: C7-MAP3-MAP4-C12

In figure 5, we present the throughput computed on different routes for K = 5. We see that when increasing transmission probability P_i the model produces more throughput after that it decreases gradually. This diminution is justified by the presence of collisions.

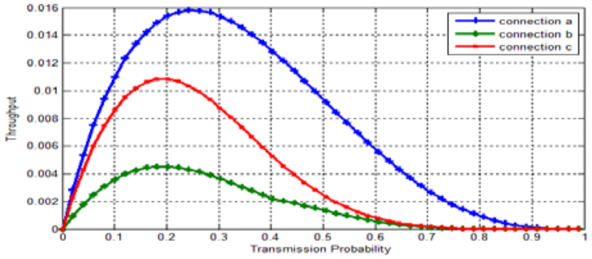

Fig. 5 Throughput vs. Transmission Probability for K = 3 and f=0.5

Figure 6 shows the throughput for K = 10 and f = 0,5. We see that increasing the bound on attempts k significantly improves the throughput on different routes.

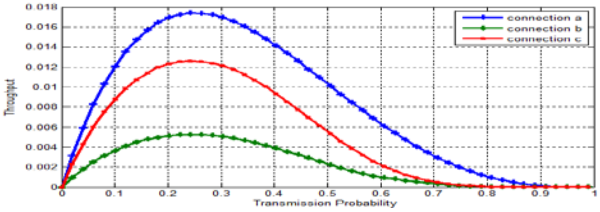

Fig. 6 Throughput from analytical model for K = 10 and f=0.5

In figure 7, we compare the throughput formed with respect to the number of hops in the wireless mesh network. As the number of hops increased, the throughput decreased in the route.

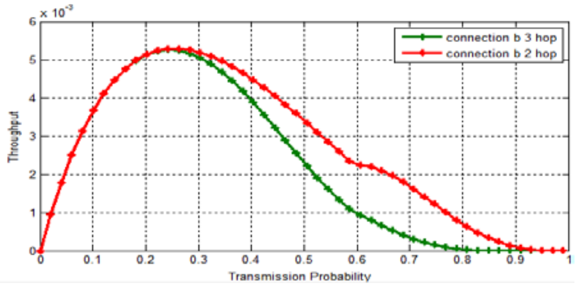

Fig. 7 Throughput vs. transmission probability for hops 1,2 and 3

With varying number of BSS connections, figure 8, we observe that our model gives more throughput for a less number of mesh clients in BSS structure.

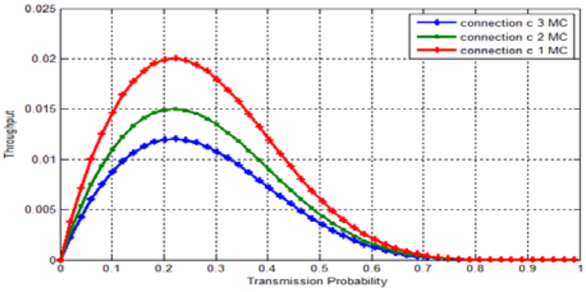

Fig. 8 Throughput vs. transmission probability for mesh clients 1,2 and 3

6. Conclusion

In this paper, we proposed an analytical model to calculate the throughput of the 802.11s network by using a cross-layer architecture that takes many parameters concerning network and MAC layers. Our main result is the characterization of the throughput performance of wireless mesh network using the rate balance. We have proposed a framework that takes account the possibility of limited number of transmission of a packet at each node after which it is dropped.

As a first result, the throughput is highly dependent of the transmission probability P_i and when we increase significantly the bound on attempts k improves the throughput. We have also studied the impact of hop count and BSS connections on throughput performance.

An ongoing work consists on improving throughput performance of real-time applications based on service differentiation mechanism.

References

[1] Akyildiz, I. F., & Wang, X. (2005). A survey on wireless mesh networks.Communications Magazine, IEEE, 43(9), S23-S30.

[2] Y. Yang, Jennifer C. Hou, Lu-Chuan Kung, Modeling the effect of transmit power and physical carrier sense in multihop wireless networks, Infocom, Alaska, 2007.

[3] Z. Cai, M. Lu, and X. Wang, “Distributed Initialization Algorithms for Single-Hop Ad hoc Networks with Minislotted Carrier Sensing,” IEEE Trans. Parallel and Distributed Systems, vol. 14, no. 5, pp. 512-528, May 2003.

[4] R. El-Azouzi, S. K. Samanta, E. Sabir and R. El-Koury, “Asymptotic Delay Analysis and Timeout-based Admission Control for Ad hoc Wireless Networks,” in the proceedings Ad hoc-Now, Murcia, Spain, 22-25 September 2009.

[5] Kherani, A., El-Khoury, R., El-Azouzi, R., & Altman, E. (2008). Stability–throughput tradeoff and routing in multihop wireless ad hoc networks.Computer Networks, 52(7), 1365-1389.

[6] R. El Azouzi , R. El Khoury , A. Kobbane , E. Sabir, “On Extending Coverage of UMTS Networks Using an Ad-Hoc Network with Weighted Fair Queueing,” Networking 2008, Ad hoc and Sensor Networks, Wireless Networks, Next Generation Internet , 7th International IFIP-TC6 Networking Conference, Singapore, May 5-9, 2008, Proceedings pp.135-148 2008.

[7] A.Loutfi, E.Sabir, Abdellatif Kobbane, Mohammed El Koutbi, “A Cross-layer Model for Service Differentiation in Wireless Sensors Networks,” the International conference on Networked Systems (NETYS 2013), Marrakech, Morocco, May 2-4, 2013.

[8] Bianchi, G. (2000). Performance analysis of the IEEE 802.11 distributed coordination function. Selected Areas in Communications, IEEE Journal on,18(3), 535-547.

[9] Draft Standard for Information Technology - Telecommunications and Information Exchange Between Systems - LAN/MAN Specific Requirements - Part 11: Wireless Medium Access Control (MAC) and physical layer (PHY) specifications: Amendment: ESS Mesh Networking, IEEE Unapproved draft P802.11s/D1.06, Jul. 2007.

[10] IEEE 802.11 WG, Draft Supplement to standard for Telecommunications and Information Exchange Between Systems - LAN/MAN Specific Requirements - Part 11: Wireless Medium Access Control (MAC) and physical layer (PHY) specifications: Medium Access Control (MAC) Enhancements for Quality of Service (QoS), IEEE 802.11e/D13.0, Jul. 2005.

[11] Y. Yang, Jennifer C. Hou, Lu-Chuan Kung, Modeling the effect of transmit power and physical carrier sense in multihop wireless networks, Infocom,Alaska,2007.