Analytical Evaluation of Proactive Routing Protocols with Route Stabilities under two Radio Propagation Models

M. Umar khan, Imad Siraj, Nadeem Javaid
Center for Advanced Studies in Telecommunication
(CAST), COMSATS Institute of Information Technology
Islamabad, Pakistan
umar_khan, imadsiraj, njaved @comsats.edu.pk

Abstract*— This paper contributes to modeling links and route stabilities in three diverse wireless routing protocols. For this purpose, we select three extensively utilized proactive protocols; Destination-Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR) and Fish-eye State Routing (FSR). We also enhance the performance of these protocols by modifying default parameters. Optimization of these routing protocols are done via performance metrics, i.e., average Throughput, End to End Delay (E2ED) and Normalized Routing Load (NRL) achieved by them. Default routing protocols DSDV, OLSR and FSR are compared and evaluated with modified versions named as M-DSDV, M-OLSR and M-FSR using Network Simulator (NS2). Numerical Computations for Route Stabilities of these routing protocols through a mathematical modeled equation is determined and compared with simulation results. Moreover, all-inclusive evaluation and scrutiny of these proactive routing protocols are done under the MAC layer standards 802.11 DCF and 802.11e EDCF. In this way both Network and MAC layer exploration has been done under the performance metrics which gives overall performance and tradeoff with respect to full utilization of the available resources of Ad-hoc network high scalability scenario. Routing latency effects with respect to route stabilities and MAC layer standards 802.11 and 802.11e are compared and scrutinized with the tradeoff observed in throughput and in overhead (NRL) generated.

Keywords-802.11;802.11e;DCF;EDCF;MANETs;Ad-Hoc

I. INTRODUCTION

IEEE standard 802.11, at present, is a significant and trendy access methodology used in wireless communication. It enables speedy and straightforward design of network communication as a *de facto* MAC standard for LANs, WANs in Small Office Home Office (SOHO) or open-places and to the highest degree facilitated wireless access to the internet. Growing esteem of 802.11 standard, numerous services also improved and requirement for Quality of Service (QoS) become obvious. Hence, therapy to QoS setback in 802.11, enhanced version, i.e., 802.11e was anticipated [1]. IEEE standard 802.11e, i.e., EDCF (Enhanced Distributed Channel Function) defines numerous QOS parameters to IEEE standard 802.11 Distributed Coordination Function (DCF).

Conferring to 802.11 DCF, every station with a fresh data packet equipped to access transmission observers channel activity while waiting for an unused period comparable to a Distributed Inter- Frame Space (DIFS) is sensed and at that point the station transmits. Else, when channel is intuited busy, station initializes its back off timer and delays the transmission access for arbitrarily chosen back off interval so to lessen aggregate of collisions.

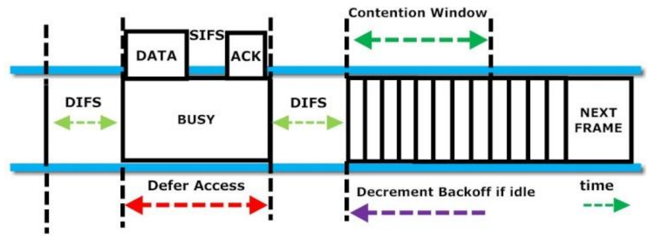

Figure 1. Basic Access Mechanism 802.11

The basic access mechanism is illustrated in the Fig.1. The EDCF, 802.11e standard announces service differentiation compared to the DCF standard 802.11 DCF by launching four access categories or classes (ACs) for data priorities [2,3]. Presuming QoS Stations (QSTAs) work under saturated or congested traffic, i.e., each QSTA has a data unit called as MAC Protocol Data Unit (MPDU) to correspond later while closing all succeeded transmissions [4]. Standard 802.11e methodology is formulated on four Access Categories (ACs); 1. Voice, 2. Video, 3. Best Effort, 4. Background.

Rest of the paper is organized as follows. Section II contains brief description of proactive protocols in ad-hoc networks. Related work and shortcomings from previous work can be found in Section III. Section IV determines the route scalabilities with the proposed mathematical equation. Simulation result analysis has been done in Section V and finally conclusion with some insight of future work is discussed in Section VI.

II. PROACTIVE PROTOCOLS IN AD-HOC NETWORK

DSDV [5], FSR [6] and OLSR [9] which are proactive in nature are table driven protocols. They update their routing table periodically without demand, so issue of extra band width utilization occurs. Several methods are designed to compensate this problem. In the Low Scalability region, all three protocols perform well, but when we take a look at Medium Scalability region OLSR has better performance. This makes this standard efficient by checking the medium state more rapidly than 802.11. In this way, time consumed for accessing the medium is decreased and more enhanced Throughput is achieved in shorter time than that in 802.11 DCF. The enhanced version 802.11e EDCF provides small Contention Window (CW) size which helps to access the medium more immediately than in 802.11e EDCF.

A. Proactive Protocols in Brief

The three extensively utilized protocols in Ad-hoc Networks that we considered Destination Sequenced Distance Vector (DSDV) [5], Fish-eye State Routing (FSR) [6], [7] and Optimized Link State Routing (OLSR) [8], [9], are proactive in nature. Altogether, these three proactive protocols practice hop-by-hop routing scheme designed for packet forwarding. In DSDV, packets are disseminated and then path is calculated by Distributed Bellman Ford (DBF) algorithm. In FSR, DBF algorithm is utilized for path calculation. The nodes keep up a table carrying link state information constructed on fresh statistics acknowledged via adjacent nodes. In addition, nodes occasionally interchange it with confined neighbors. Path calculation mechanism in OLSR is carried out through Dijikstra's algorithm [9]. Proactive routing protocols in brief with their features are given below in Table I.

TABLE I. PROACTIVE FEATURES IN BRIEF

Features	DSDV	OLSR	FSR
Path Calculation	DBF Algo	Dijikstra's Algo	DBF Algo
Flooding Control Mechanism	Exchange topology info with neighbors	Broadcast via selected MPRs	Graded Frequency mechanism
Overhead Reduction	Incremental updates	MPRs	Fish-eye technique
Packet Forwarding	Hop by Hop routing	Hop by Hop routing	Hop by Hop routing
Special Features	Route Settling Time	MPRs	Multi-Scope Routing

III. RELATED WORK AND SHORTCOMINGS

After the extensive research concerning to our contribution, we have summarized the previously done work and its shortcomings with the help of Tables VI and VII.

IV. MODELING ROUTE STABILITIES

Modeling Route Stabilities of these three proactive routing protocols are determined depending upon their broadcast time interval *Tbi*. Numerical computation is carried out for each proactive routing protocols. Route stabilities are determined using the following equation (1). Suppose, we have two nodes *na* and *nb*. Node *na* transmits a packet at time *tj* which is received by *nb* at time *tk*. Link stability at node *nb*, for link *l*, at time *tk*, for a particular broadcast interval *TBi* with respect to certain routing protocol parameters, $Stability_{nb}^{l}(t_k)$ can be defined as follows:

$$Stability_{nb}^{l}(t_k) = \frac{t_k\,(na) - t_j\,(na)}{T_{Bi}} \qquad (1)$$

The above equation is accompanied by the following constraints:

(i) $\forall\, k > 0$
(ii) $T_{Bi} \neq 0$
(iii) $0 < T_{Bi} < 1$ (Ideal Situation)
(iv) $Stability_{nb}^{l}(t_k) < T_h$, where T_h is a threshold value defined through specific parameter which varies from protocol to protocol.

A. DSDV Route Stabilities

In case of Trigger Updates between active links, T_{Bi}^{DSDV} varies according to state of the link. When link breaks, trigger messages are sent by the respective node by increasing NRL.

For T_{Bi} = 0.01, $T_h \leq 5$ and for T_{Bi} = 0.07, $T_h \leq$ 0.71, so $0.1 \leq T_{Bi} \leq 0.7$

TABLE II. NUMERICAL COMPUTATIONS FOR DSDV

Parameters	Default Value	Modified Value
$T_{Bi}(s)$	.0588	0.1176
$T_h \leq$	0.85	0.425
Stability	0.017	0.0085

B. OLSR Route Stabilities

TABLE III. NUMERICAL COMPUTATIONS FOR OLSR

Parameters	Inner Scope		Outer Scope	
	Default Value	Modified Value	Default Value	Modified Value
TTL	2	2	255	255
$T_{Bi}(s)$	5s	1s	15s	3s
$T_h \leq$	0.01	0.05	0.0033	0.016
Stability	0.00002	0.001	0.00006	0.003

C. FSR Route Stabilities

TABLE IV. NUMERICAL COMPUTATIONS FOR FSR

Para-meters	TC Messages		Hello Messages	
	De-fault Value	Modified Value	De-fault Value	Modified Value
$T_{Bi}(s)$	5s	3s	2s	1s
$T_h \leq$	0.01	0.016	0.025	0.05
Stability	0.0002	0.0003	0.0005	0.001

TABLE V. SIMULATION PARAMETERS

Parameters	Values	Parameters	Values
Bandwidth	2Mb	Simulation Time	900 sec
Packet size	1000 B	Interface Queue	50
Speed	15 m/s	Channel Type	Wireless
Traffic type	UDP, CBR	Nodes	10 - 100

TABLE VI. RELATED WORK AND SHORTCOMINGS

Related Work	**Scalability (Nodes)**	**Performance Metrics**	**MAC Layer Standard Reasoning**	**Modified Parameters and Modeling Route Stabilities**
In [10] Samar R Das *et al*	30 & 60	Throughput, E2ED, NRL	Not Considered	NOT CONSIDERED
In [11]Bianchi *et al*	50	other	Not Considered	
In [12] Daneshgram *et al.*	20	Throughput, E2ED, NRL	802.11	
D. Malone *et al*. [2] & Engelstad *et al.* [3]	20	other	802.11/802.11e	

TABLE VII. RESULTS AND MODIFICATIONS

	Scalability (Nodes)	**Performance Metrics**	**MAC Layer Standard Reasoning**	**Modified Parameters and Modeling Route Stabilities**
Our Work	10 to 100	Throughput, E2ED, NRL	802.11/802.11e	Modification in Default Parameters of Protocols and Mathematical Modeling is done

V. SIMULATIONS AND RESULTS

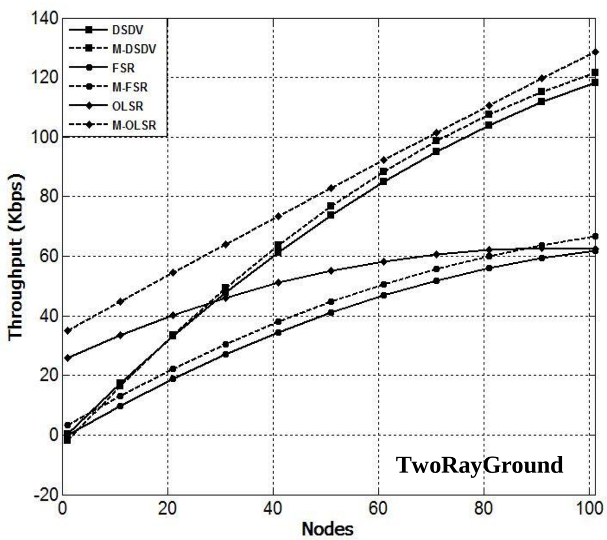

Figure 2. Throughput 802.11 DCF

In high scalabilities, (Fig. 2 and Fig. 3) MPR techniques achieve more optimization and efficiency, therefore both OLSR and M-OLSR overall produce high throughput among selected proactive protocols. After modification in all of three chosen protocols, OLSR produces the highest throughput both in DCF and EDCF. It is because of the frequent updating of routing messages that results in stabilized MPRs. DSDV achieves the second highest average throughput in DCF and EDCF as compared to the rest of two selected routing protocols. The reason for high efficiency of DSDV is due to incremental updates which are generated in case of any change in links of active routes.

But in high scalabilities it fails to converge because the exchange of routing messages through flooding cause more overhead, and in high densities the rate of change is increased, thus causes more drop rates. On the other hand, OLSR's throughput is more in high scalabilities of 80 nodes, 90 nodes and 100 nodes because MPRs provide more optimizations in high densities.

However, FSR use only periodic updates for link status monitoring and route updating. It is more suitable for hundreds and thousands of nodes, because fish-eye scopes with graded frequency mechanisms are best suited in very high densities. Frequent routing updating in FSR by reducing inner-scope and outer-scope intervals augments more throughputs in FSR-M as compared to FSR, but FSR-M fails to converge in EDCF comparative to that of FSR. Whereas, increasing the interval of triggered update generation in DSDV-M increase throughput in EDCF while inDCF.

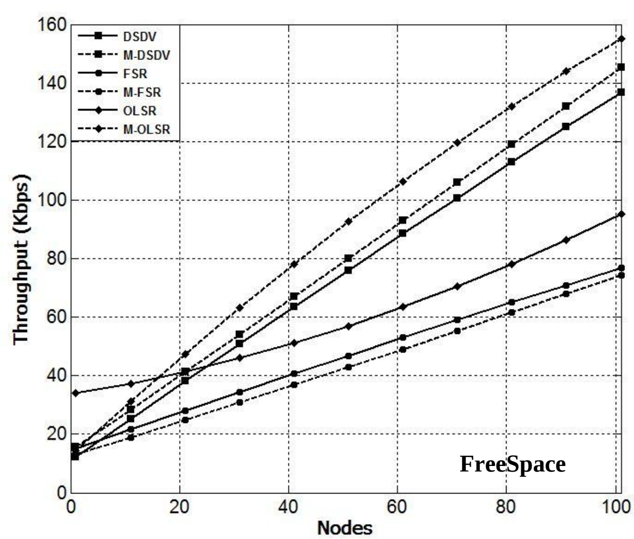

Figure 3 Throughput 802.22 EDCF

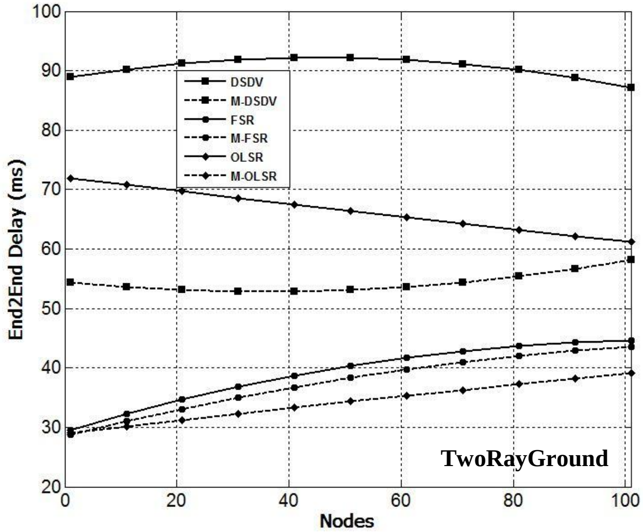

Figure 4. End2End Delay 802.11 DCF

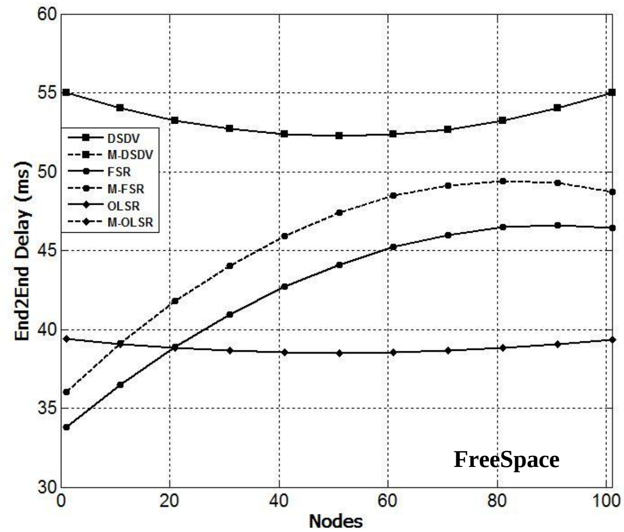

Figure 5. End2End Delay 802.11 EDCF

In Fig. 4 and Fig. 5, E2ED of selected routing protocols is less in EDCF as compared to DCF due to efficient stability checking of link in EDCF comparative to DCF. FSR attains the lowest routing latency in DCF as compared to DSDV and OLSR. Pure proactive approach route updating keeps overall routing latency low in FSR. Although in DSDV data remains for the time required for route settling to maintain correct information of routes before sending it to the destination, but this route settling time augments the delay. Whereas, DSDV produces the highest delay, moreover, it does not optimize network wise broadcasting (in DSDV exchange of routing messages is only performed through flooding, as compared to MPRs of OLSR which reduce number of retransmissions and scope updates of FSR by using graded frequency mechanism).

DSDV-M has less routing latency as compared to DSDV in case of DCF. While DSDV-M and DSDV possess equal routing delay in EDCF, because efficient mechanism of 802.11e EDCF helps to reduce E2ED. Same is the case of OLSR, where OLSR-M achieves lowest delay as compared to OLSR in EDCF, while this delay is more in EDCF. As FSR-M's periodic intervals for scope routing are reduced, therefore it attains low E2ED in both DCF and EDCF. Moreover it does not update routing information instantly after detection of any change in the network unlike DSDV and OLSR; therefore, EDCF mechanism does not effect too much to improve its performance.

All selected routing protocols have attained high NRL referring to Fig. 6 and Fig. 7 after modifications. The rate for successive routing messages exchange is highest in OLSR as compared to the rest of the protocols (clearly mentioned in the table), therefore it generates high routing load. As FSR does not trigger any routing messages in case of link breakage and relies only on periodic updating, thus it produces lowest NRL in DCF. Furthermore, DSDV produces lowest routing messages in case of EDCF as compared to OLSR and FSR as shown in Fig. 6, because the efficient information of link connectivity reduces incremental updates. TTL value in ring search algorithm increases while increase in network density is observed, this leads to increase in broadcast routing packets during route discovery as increasing NRL behavior in FSR.

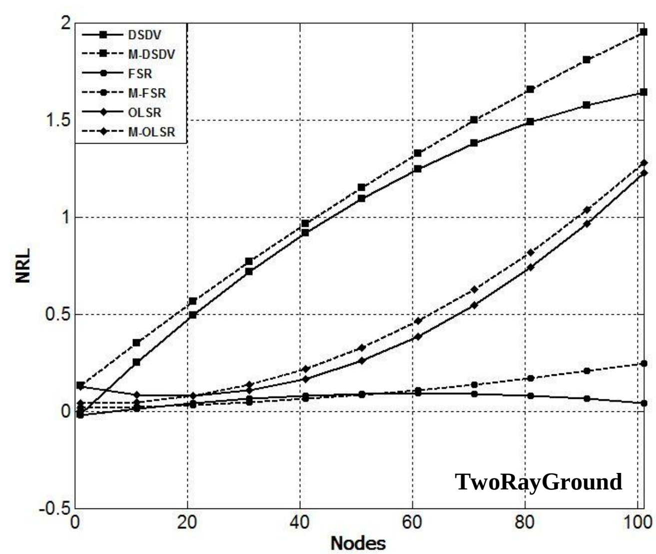

Figure 6. NRL 802.11 DCF

 ISBN: 978-1-61208-267-7

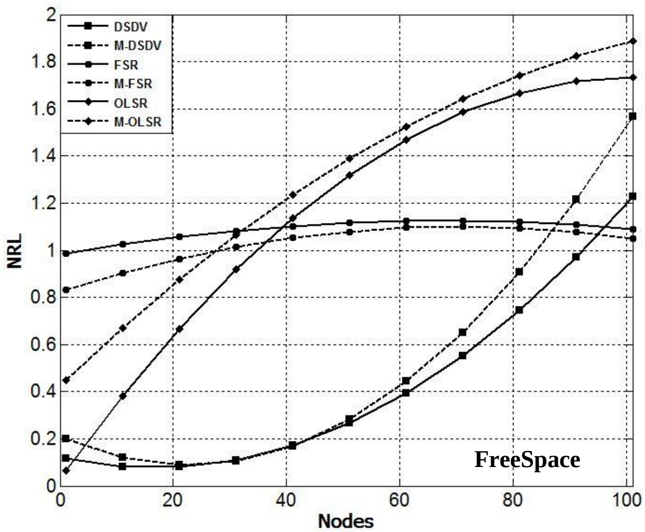

Figure 7. NRL 802.11 EDCF

TABLE VII. DEFAULT AND MODIFIED PARAMETERS

Protocols	Default Parameters	Modified Parameters
DSDV	T*bi* = 15 s or 8/15 = .0588 s	T*bi* = 10 s or .1176 s
OLSR	TC_Messages = 5 s Hello_Messgaes = 2 s	TC_Messages = 3 s Hello_Messgaes = 1 s
FSR	T*bi* = 5 s	T*bi* = 1 s

Performance Trade-offs of three proactive routing protocols; DSDV, OLSR and FSR as shown in Fig. 7 according to three performance metrics carried out on the basis of simulation results analysis. DSDV achieves enhanced and high throughput with trade-off between E2ED but reduction in routing overhead is observed using incrementals. OLSR outperforms as concerned to its lowest E2ED observed with the increase in throughput and normalized routing load. FSR produces more normalized routing load with a minimum trade-off between other two performance metrics, i.e., throughput and E2ED.

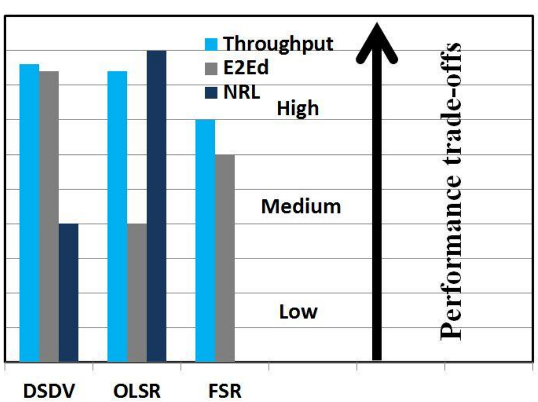

Figure 8. Performance trade-offs

VI. Conclusion and Future Work

In this paper, we have estimated and matched the performance of three extensively utilized proactive protocols; DSDV, OLSR and FSR. Total normalized routing load achieved by a protocol which is centered upon two changing aspects; control traffic produced by control packets and data traffic accelerated over and done with routes of non-optimal path lengths. Consequently, for evaluating the route stabilities of these protocols in dense networks and with different broadcast intervals of each routing protocol; we have varied different scalability scenarios. In lieu of analysis, three performance parameters; E2ED, NRL and throughput are worked out by using NS-2. In conclusion, we perceived that OLSR is additionally scalable for the reason of bargain in routing overhead due to MPRs and lowest E2ED, as OLSR permits retransmission via MPRs. On the other influence, FSR is supplementary appropriate for extraordinary network loads owed to scope routing over GF (no flooding), that decreases broadcasting storm, as a result it saves additional bandwidth and accomplishes high throughput when data traffic upturns in high scalabilities.

In the future, we are concerned to evaluate reactive routing protocols under same scalability scenarios, but with varying mobilities and under route stabilities computed using the equation proposed in (1).

References

[1] Peter Clifford, et al., "Modeling 802.11e for data traffic parameter design," Hamilton Institute, Ireland, 2008.

[2] D. Malone, et al., "Modeling the 802.11 distributed coordination function in non-saturated heterogeneous conditions," IEEE/ACM Transactions on Networking, 2007.

[3] P.E. Engelstad, et al., "Non-saturation and saturation analysis of IEEE 802.11e EDCA with starvation prediction," ACM International Symposium, 2005.

[4] J. Hu, et al., "A comprehensive analytical model for IEEE 802.11e QoS differentiation schemes under unsaturated traffic loads, in: Proceedings of the ICC08," 2008.

[5] C. E. Perkins and P. Bhagwat, "Highly dynamic Destination-Sequenced Distance-Vector routing (DSDV) for mobile computers," SIGCOMM Comput. Commun. Rev, vol. 24, pp. 234-244, 1994.

[6] G. Pei, et al., "Fisheye State Routing in Mobile Ad Hoc Networks," in ICDCS Work-shop on Wireless Networks and Mobile Computing, 2000, pp. D71-D78.

[7] M. Gerla, et al., IETF Draft-01, "Fisheye State Routing Protocol (FSR) for Ad Hoc Networks," 2000.

[8] T. Clausen and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)," 2003.

[9] T. Clausen and P. Jacquet, IETF RFC-3626, "Optimized Link State Routing Protocol OLSR," The Internet Society http://www. ietf. org/rfc/rfc3626. txt, 2003.

[10] Samir R. Das, et al., "Simulation-based performance evaluation of routing protocols for mobile ad hoc networks".

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

[12] F. Daneshgaran, et al., "Unsaturated throughput analysis of IEEE 802.11 in presence of non-ideal transmission channel and capture effects," IEEE Transactions on Wireless Communications 7 (4) (2008) 12761286

 ISBN: 978-1-61208-267-7