

Power optimized modified algorithm to increase Network capacity in wireless communications

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Abstract: In this paper an approach is proposed considering the Transmission Rate Adaptation for all 802.11 supporting a collection of transmission rates with reliable decoding of a higher rate demands at higher link quality for power optimized communication. Recent advances in physical layer technologies, e.g., ultra wideband (UWB), multiple-input and multiple-output (MIMO), and cognitive radio (CR), have made profound impact on wireless networks. In this work, CR is considered which a revolution in radio technology is. CR is enabled by recent advances in RF design, signal processing, and communication software.

Keywords: Wireless Network, Cognitive Radio, Network Layer, Link Layer, Physical Layer, BER, SNR.

I. INTRODUCTION

In recent years, there have been significant advances in wireless networking. Such advances are improved by the demand of new practical and military applications as well as advances in wireless communication technology at the communication layer. These new advances at upper and lower layers in communication have brought many new research problems for networking researchers. Among these problems, a fundamental problem is to determine performance limits and to design a system to achieve these limits. Due to new requirements (performance metrics) by these new applications and unique characteristics (constraints) associated with these wireless networks, traditional analytical approaches are no longer adequate. In this work, several new approaches to study the performance limits for wireless networks and mobile networks are developed. Wireless networks can be used to quickly build a network for peer-to-peer communication without first establishing a fixed infrastructure. Nodes in a wireless network are able to organize themselves into a multi-hop network for wireless communications. Wireless networks can be used where communication infrastructure is not available [1]. Recent advances in physical layer technologies, e.g., ultra wideband (UWB), multiple-input and multiple-output (MIMO), and cognitive radio (CR), have made profound impact on wireless networks. In this work, CR is considered which a revolution in radio technology is. CR is enabled by recent advances in RF design, signal processing, and communication software [3]. Fundamental characteristics of CR are that transmitted waveforms are defined by software and that received waveforms are demodulated by software. This is in contrast to traditional hardware based radios in which processing is done entirely in custom-made hardware circuitry. CR promises unprecedented flexibility in radio communications and is viewed as an enabling technology for dynamic spectrum access (DSA). For CR networks, spectrum sharing among CR nodes is considered. A new

metric, called bandwidth footprint product (BFP) is proposed to measure CR nodes' resource usage in both spectrum and space. To explore the performance limits of these new wireless networks, it is necessary to consider characteristics and constraints at multiple layers (i.e., power control at the physical layer, scheduling at the link layer, and routing at the network layer). Such problems are typically very complex, involving nonlinear, possibly non-convex relationship or constraints. As a result, developing theoretical results for these problems are very challenging and previous work are mostly heuristics without any performance guarantee. In this work, several efficient algorithms to provide optimal or near-optimal solutions for these problems are developed.

II. SYSTEM ARCHITECTURE AND APPROACH

For the realization of the proposed objective a mobile node is implemented as an object with functionalities such as movement and the ability to transmit and receive on a channel that allows it to be used to create mobile, wireless simulation environments. In wireless network, each mobile node has one or more wireless network interfaces, linked together by a single physical channel. When a network interface transmits a packet, it passes the packet to the appropriate physical channel object. This object then computes the propagation delay from the sender to every receiver on the channel and schedules a packet reception event for each. This event notifies each receiving interface when the first bit of a new packet has arrived. After this notification, a receiver at distance d computes the received power of the packet to be $P_r = G(d)P_t$ where P_t is the transmitter power and $G(d)$ is the link gain from the transmitter to the receiver. The link gain $G(d)$ is calculated either by the Friis free space model [6],

$$G^{(1)}(d) = G_t G_r \lambda^2 / (4\pi d)^2 L \quad \text{eq.1}$$

or the two-ray ground model [26],

$$G^{(2)}(d) = G_t G_r (h_t^2 h_r^2) / d^4 L \quad \text{eq.2}$$

Note that G_t and G_r are the transmitter and receiver antenna gains which have default value 1, L is the system loss which has a default value 1, h_t and h_r are the heights of the transmit and receiver antennas which have default value 1.5 m. If d is less than the distance $d_0 = 4\pi h_t h_r / \lambda$ where $G^{(1)}(d_0) = G^{(2)}(d_0)$ the Friis equation is used. Otherwise the two-ray ground model is used to compute the received power of the packet. It follows that

$$G(d) = \min(G^{(1)}(d), G^{(2)}(d)) \quad \text{eq.3.}$$

The received power level of the arriving packet is then compared to two different values: the carrier sense threshold (CST) and the receive threshold (RXT). The CST has two functions.

- 1 If the received power level is below CST, the packet is discarded as noise; the receiver interface operates as if that packet never existed.
- 2 CST is also used for purposes of CSMA/CA. The transmitter cannot start transmission of a new packet if it senses another signal with a received power level higher than CST.

A receiver's MAC layer is modeled as a state machine with the three states.

- 1 Idle State: The MAC layer is ready to start decoding a new packet.
- 2 Receive State: The MAC layer is decoding a packet.
- 3 Collision State: While in receive state, the packet currently being decoded has suffered a collision.

In the event of a collision, the MAC layer switches into the collision state and stays in this state until the both colliding packets have completed transmission. This rule prevents the transmitter interface from starting a new transmission during the transmission of the colliding packet. For a transmitter, this behavior is consistent with the CSMA/CA standard, which prevents a new transmission when there is a packet in the medium with a received power level higher than CST. However, this behavior also prevents the receiver interface from attempting to receive any new packets until the colliding packet reception ends.

a) Interference Limiting Model

In systems with interference from other users, it is common practice to model the communication link quality by the signal to interference plus noise ratio (SINR) [7-9]. To formulate the SINR, on communication link j , transmitter j employs power P_j to send to receiver j . G_{ij} is used to denote the power gain from the link j transmitter to the link i receiver. At the link i receiver, the SINR is,

$$\gamma_i = \frac{G_{ii} P_i}{\sum_{j \neq i} \theta_{ij} G_{ij} P_j + \eta} \quad \text{eq.4}$$

Note that η is the in-band receiver noise power and includes both thermal noise as well as the receiver noise figure. In addition, θ_{ij} represents the fraction of transmitter j 's received signal power that is projected onto the signal

space of user i . For example, in a synchronous CDMA system with matched filter detection, μ_{ij} equals the normalized squared cross-correlation between the signature sequences of users i and j . In general, the interference factor μ_{ij} may depend on the spreading codes, modulation formats, and data rates of the users. Analysis has also shown that μ_{ij} may also depend on such factors as the synchronism (or asynchronism) of the users' transmissions [3] as well as receiver hardware implementation design choices such as the number of bits in the analog to digital converter [13]. In certain spread spectrum systems, μ_{ij} may be reduced if the receiver employs filtering in the form of multiuser detection [14]. The interference factor μ_{ij} may also model interfering signals that overlap the frequency spectrum of user i . For a link i transmitting at data rate R_i b/s, a common model in spread spectrum systems with matched filter detection is to assume that $\mu_{ij} = \mu_i = R_i / W$, corresponding to the reciprocal of the processing gain $N_i = W / R_i$. Prior analyses of CDMA systems that concluded μ_i is proportional to $1 / N_i$ were based on the assumption that both the processing gain N_i and the number of interfering users are relatively large. For example, second generation cellular CDMA systems employ a processing gain of 128 and support 10-20 simultaneous transmissions in a single cell.

b) Communication Packet Modeling

A physical model for packet reception consistent with the IEEE 802.11 protocol is adopted. When the receiver is in the idle state and the received power level of a new packet is higher than CST, the MAC layer enters the receive state and stays in this state until that packet transmission is complete.

In this work, a BER based model that describes a system with uncoded packets in which the detector makes a hard decision on each transmitted bit is referred. This BER based model probabilistically decides whether each bit in a packet is transmitted correctly based on the receiver SINR during that bit reception. At every node, the total received power P_{total} from all signal sources is stored and is updated every time a packet transmission begins or ends. SINR tracking is implemented just by tracking the total received power as follows:

- 1 When a new packet arrives, increase P_{total} by the received power of that packet.
- 2 When a packet completes transmission, decrease P_{total} by the received power of that packet.

If a node is receiving a packet with received power P_r and the total received power is P_{total} , the SINR is

$$\gamma = \frac{P_r}{\theta [P_{total} - P_r] + \eta} \quad \text{eq.5}$$

For packet decoding, define a segment as a consecutive sequence of received bits over which the SINR is constant. In our BER-based model of packet reception, whether a packet has errors as a function of the SINR in each packet segment is determined. Based on these segments, the packet reception algorithm is:

1 For a given segment, find the bit error rate by using the pre-computed BER-SINR table.

2 If the segment has n bits, calculate the probability

$$P_C = (1 - P_e)^n \quad \text{eq.5}$$

that all bits in the segment are decoded correctly.

1 Throw a uniform random variable between 0 and 1. If this number is greater than PC, mark this segment with error.

2 At the end of decoding a packet transmission, check if there was a decoding error in any packet segment. If so, discard the packet; otherwise, the packet is received correctly. Note that the IEEE 802.11b standard does not use coding. Thus if there is a single segment with error, that packet will fail a CRC check.

As observed, a BER-SINR look-up table for our packet reception model is designed. For the BER of DBPSK the following equation is given by,

$$P_e = \frac{1}{2} e^{-\gamma_b} \quad \text{eq.6}$$

Here γ_b is the SINR per bit. For DBPSK, γ_b is equal to γ . For BER of DQPSK, the following equation is used

$$P_e = Q_1(a, b) - 0.5 I_0(ab) e^{-2\gamma} \quad \text{eq.7}$$

Where,

$$a = [2\gamma_b(1 - 1/\sqrt{2})]^{1/2}$$

$$b = [2\gamma_b(1 + 1/\sqrt{2})]^{1/2}$$

$Q_1(a, b)$ is Marcum Q function and I_0 is the modified Bessel function of the first kind of order 0. For DBPSK, γ_b is equal to $\gamma/2$. This is because of the fact that in 2Mbps data rate the energy used for transmitting a single bit is the half of the energy that's used in 1Mbps.

III. RESULTS AND OBSERVATIONS

To evaluate the variation of BER over variable SNR a performance analysis is carried out at different data rate and the observation made is as outlined below,

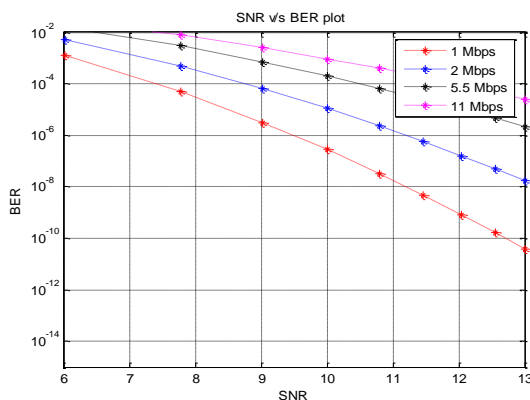


Figure 1: SNR v/s BER at variable data rate

The codeword can be decided correctly when both B1 and B2 have been decided correctly.

c) Carrier Sensing

In the original implementation, physical carrier sensing is handled by a timer. When there is a packet with a received power higher than CST the timer is set to the end of that packet's transmission. So, when the packet's transmission ends, the MAC layer switches to idle state assuming no other packet is currently being transmitted or received and RTS/CTS option is turned off. This implementation is modified in the following way:

1 When a packet with a received power higher than CST arrived at the node the timer is set just like in the original code.

2 When this timer expires, the MAC layer checks if the total received power level at the node is lower than CST. If it's lower, the wireless medium is indicated as idle.

3 If the total received power at the node is still higher than the CST, the medium cannot be indicated as idle until the total received power drops below CST. In order to check if this is the case, after the ending of every single packet's transmission the node compares the total received power to the CST.

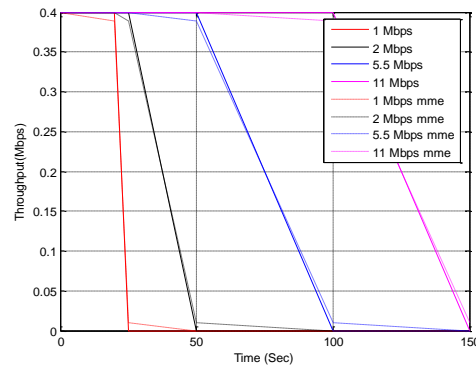


figure 2: throughput for transmit power $P_t=10\text{dbm}$ with 512-byte packets

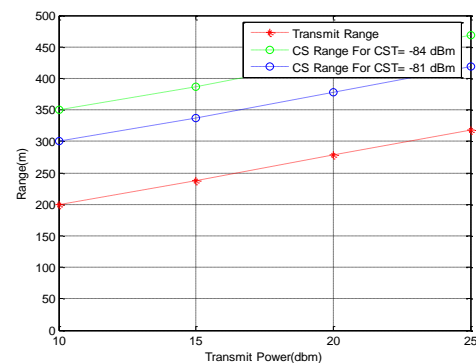


Figure 3: transmitted power v/s range plot at variable noise level

For the observations obtained for the transmitted power at $CST = -84 \text{ dBm}$, the packet delivery ratios for source routing and demand routing protocol are observed very similar with transmit power P_t higher than 16 dBm. When the transmit power is lower than 16 dBm, demand routing protocol outperforms source routing in terms of packet delivery ratio.

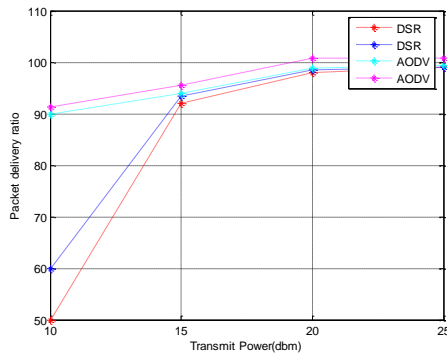


Figure 4: Transmitted power over packet delivery ratio for the routing schemes developed.

An experiment with the PHY layer data rates is carried out. However, when using a specific rate for the unicast data packets, the choice of rate used for the broadcast data packets and the MAC control packets can dramatically affect the results as shown below.

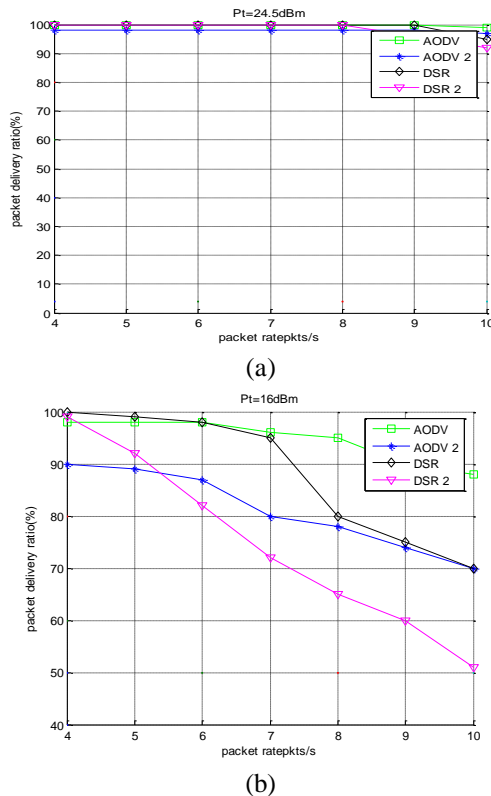


Figure 7: packet rate over packet delivery ratio for (a) at 24.5dB and (b) 16dB transmitted data power

IV. CONCLUSION

In this work, the effect of different physical layer models on the performance evaluation of higher layer protocols is developed. The differences between suggested approach and model under typical large-scale scenarios used for the performance evaluation of wireless network routing protocols is evaluated. With tunable 802.11 parameters such as CST and RTS/CTS threshold, the proposed approaches give better results than that of conventional models. It is observed that, while increasing the CST value

increases the packet delivery ratio because the numbers of instantaneous transmissions increase. In this work the Transmission Rate Adaptation for all 802.11 supporting a collection of transmission rates is proposed with reliable decoding of a higher rate demands a higher link quality. Thus higher rate transmissions will have a shorter range, or require higher power to maintain the same range.

REFERENCES

- [1] Lee Breslau, Deborah Estrin, Kevin Fall, Sally Floyd, John Heidemann, Ahmed Helmy, Polly Huang, Steven McCanne, Kannan Varadhan, Ya Xu, and Haobo Yu. Advances in network simulation. *IEEE Computer*, 33(5):59-67, May 2000.
- [2] S. R. Das, C. E. Perkins, and E. M. Royer. Performance Comparison of Two On- Demand Routing Protocols for Wireless Networks. In *Proc. of the IEEE INFOCOM 2000 Conference*, March 2000.
- [3] D. Maltz, J. Broch, J. Jetcheva, and D. Johnson. The Effects of On-Demand Behavior in Routing Protocols for Multi-Hop Wireless Networks. *IEEE Journal on Selected Areas in Communication*, 17, August 1999.
- [4] William H. Tranter, K. Sam Shanmugan, Theodore S. Rappaport, and Kurt L. Kosbar. *Principles of Communication Systems Simulation with Wireless Applications*. Prentice- Hall, 2012.
- [5] M. Bansal and G. Barua. Performance comparison of two on-demand routing protocols for mobile wireless networks. In *IEEE International Conference on Personal Wireless Communications*, pages 206-210, December 2002.
- [6] T.D. Dyer and R.V. Boppana. Routing http traffic in a mobile wireless network. In *Proceedings of MILCOM*, volume 2, pages 958-963, October 2002.
- [7] E.M. S. Gwalani, Belding-Royer and C.E. Perkins. Demand routing protocol-pa: Demand routing protocol with path accumulation. In *IEEE International Conference on Communications*, volume 1, pages 11-15, May 2003.
- [8] N. Bai, F. Sadagopan and A. Helmy. Brics: a building-block approach for analyzing routing protocols in wireless networks-a case study of reactive routing protocols. In *IEEE International Conference on Communications*, volume 6, pages 3618-3622, June 2004.
- [9] D. Sun and H. Man. Tcp α -based performance analysis of two on-demand routing protocols for mobile wireless networks. In *Vehicular Technology Conference VTC 2001 Fall*. *IEEE VTS 54th*, volume 1, pages 272-275, 2001.
- [10] J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu, and J. Jetcheva. A Performance Comparison of Multi-hop Wireless Network Routing Protocols. In *Proc. Of Fourth Annual ACM/IEEE Int. Conf. Mobile Computing and Networking*, pages 85- 97, October 1998.
- [11] N. Hedman B. Mielczarek P. Johansson, T. Larsson and M. Degermark. Routing protocols for mobile ad-hoc networks - a comparative performance analysis. In *Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM)*, pages 195-206, 1999.
- [12] S. Das, R. Castaneda, and J. Yan. Simulation based performance evaluation of mobile, wireless network routing protocols. *ACM/Baltzer Mobile Networks and Applications (MONET) Journal*, pages 179-189, July 2015.
- [13] G. Holland and N. H. Vaidya. Analysis of tcp performance over mobile wireless networks. In *Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM)*, pages 219-230, 1999.
- [14] Y. C. Hu and D. Johnson. Caching Strategies in On-demand Routing Protocols for Wireless Networks. page 231242, August 2010.
- [15] Jay Martin Mineo Takai and Rajive Bagrodia. Effects of wireless physical layer modeling in mobile wireless networks. In *Proceedings of the 2nd ACM international symposium on Mobile wireless networking and computing*, pages 87-94, 2014.