Abstract—In this paper, we exploit a distributed power control algorithm for spatial time division multiple access (STDMA) medium access control (MAC) protocols. Our algorithm aims at maximizing the number of simultaneous transmissions while concurrently minimizing the corresponding transmission powers in a given time slot. We formulate the problem of interest as a linear programming (LP) problem subject to discrete constraints. Then, we solve the problem using dynamic programming (DP). Based on our solution, we propose a low complexity optimal power control algorithm which can be generically embedded into any existing STDMA MAC protocol. Through analytical and experimental studies, we show that not only our power control algorithm significantly improves the throughput performance and the power consumption of STDMA MAC protocols compared to their baseline alternatives but it also outperforms the existing power control algorithms devised for STDMA MAC protocols.

I. INTRODUCTION

In the past decade, adding power control to MAC protocols has grabbed an ever increasing attention. Some theoretical studies have shown that the proper use of power control in wireless MAC protocols can improve the aggregate channel utilization by up to a factor of $O(\rho)$ where $\rho$ is the density of nodes in a target region [1]–[3]. The use of power control schemes with the MAC protocols was originally introduced in the context of channelized cellular networks where such algorithms were implemented in a centralized way and base stations centrally controlled the channel and power assignments [4], [5]. Later, distributed iterative power control algorithms in cellular systems were proposed by [6], [7]. Power control has also been explored as one of the key design aspects of the scheduling based MAC protocols such as STDMA [8]. As evidenced by the works of [9]–[13], power control can trade off the assignment of power against the allocation of rate and consequently identify simultaneous transmissions schedule in STDMA. In this series of articles, the authors start from a centralized mixed-integer linear programming (MILP) problem that is solved with exponential complexity and reduce to a distributed heuristic algorithm called distributive power control rate adaptation link scheduling (DPRL) algorithm. DPRL is a greedy algorithm that considers the transmission scheduling problem in a two-hop interference neighborhood with a complexity of $O(m + L^2)$ where $m$ is the number of available data rates and $L$ is the number of links being scheduled. It iteratively schedules multiple transmissions in a given slot based on the highest SINR value within the two-hop neighborhood not interfering with existing transmissions. Although DPRL boosts throughput, the powers allocated for simultaneous transmissions are not optimized. Thereby, the power consumption of DPRL is relatively high. The latter forms the main motivation of our research work.

In this paper, we introduce a power control algorithm that can be used to identify optimal simultaneous transmissions in a given time slot. Our algorithm identifies assignment strategies of STDMA protocols in multi-hop wireless networks under the rate and power constrains. We formulate our optimization problem as a LP problem and solve it using DP. In order to reduce computational complexity, our DP method structures the optimization problem into independent sequential execution steps and solves them one step at a time. Accordingly, we propose a low complexity and hence practical power control algorithm to which we refer as optimal power control (OPC) algorithm to generate a per slot simultaneous transmissions schedule. Finally, we evaluate the performance of our algorithm by augmenting dynamic time slot assignment (DTSA) algorithm [14] with our proposed algorithm and comparing the results. We also compare our algorithmic results with those of the algorithm proposed in [13]. The results show that our power control algorithm can significantly improve the throughput performance of STDMA MAC protocols and reduce the corresponding power consumptions.

The rest of this paper is organized as follows. Section II introduces our analytical model. We formulate our optimization problem and present our power control algorithm in Section III. Simulation results and data analysis are provided in Section IV. Finally, Section V concludes the paper.

II. ANALYTICAL MODEL

We open this section by briefly introducing the assumptions and notations of the paper. First, the paper focuses on improving the performance of STDMA protocols that offer time slot assignment strategies guaranteeing no two nodes within a two-hop neighborhood are assigned to the same time slot. The range of one hop is defined as the transmission distance under highest power with the lowest data rate. As explained in [15], we use the concept of “Local Contention Area” (LCA) to represent a node’s two-hop neighborhood. From the standpoint of practicality, the use of LCA limits node discovery traffic to the local level as each node only concerns itself with knowing about its two-hop neighbors as oppose to all network nodes. Although we assume that the effective collision domain

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of a node is limited to its LCA, we leave some “power margin” at the receivers to mitigate interference from nodes that are more than two hops away similar to the approach of [13] and many other papers.

All nodes are assumed to be half-duplex equipped with omnidirectional antennas. Each node generates fixed length control packets and fixed length data packets. We assume no communication link changes in the duration of a time slot. Further, we assume that there are m available distinct modulation-coding schemes limiting the data rates to the discrete set \{r_1, r_2, ..., r_m\} where \( r_1 < r_2 < \cdots < r_m \). Taking the limit size and weight of all nodes in wireless multi-hop networks into account, we assume that the maximum available power to all nodes is \( P_{max} \). A successful transmission on a wireless link from node \( i \) to node \( j \) (\( l_{ij}^1 \)) can be performed when the condition below is satisfied.

\[
\frac{P_i^j G_{ij}^1}{\sum I_k^i + N} \geq \gamma(r_j^1), \quad (i \neq j \neq k)
\]  

(1)

In the inequality above, \( N \) represents the average power of the thermal noise experienced by node \( j \), \( \sum I_k^i \) is the interference power caused by other simultaneous transmissions, and \( \gamma(r_j^1) \) is the pre-specified SINR threshold which depends on many factors such as data rate, acceptable BER, and so on. Further, \( r_j^1 \) and \( P_i^j \) are the data rate from node \( i \) to node \( j \) and the corresponding power used by the transmitting node \( i \), respectively. For simplicity, we assume that the other factors remain constant during the duration of a slot and subsequently the SINR threshold is a only function of \( r_j^1 \). Finally, \( G_{ij}^1 \) represents the path loss from node \( i \) to node \( j \) and is calculated from the radio propagation model given below.

\[
G_{ij}^1 = \frac{1}{d^\theta}
\]  

(2)

In the equation above, \( \theta \) is the path loss exponent ranging from 2 for the line of sight free space environments to 4 for the indoor environments [16]. In order to capture the effects of wireless channel such as fading and shadowing, we use the method of [17], [18] to calculate packet error rate (PER). Since we consider scenarios of limited mobility in this paper, we assume a fixed gain matrix in each execution period of our algorithm. In our power control algorithm, we use the geographical position information for distance estimation [19]. We further assume that ACKs and control messages received by each node from its LCA neighbors contain the geographical position (GPS coordinates) of the transmitting node.

Our goal is to design a localized power and rate control algorithm which can be embedded within an STDMA protocol to achieve the following objectives: (i) include the maximum number of simultaneous transmissions in a given time slot, i.e., maximize the spatial reuse of the system resources, (ii) specify the set of powers and data rates of all of the simultaneous transmissions subject to SINR constraints at the receivers of all links, and (iii) offer a low time complexity. From among the three objectives above, meeting objective (ii) is the main goal, i.e., achieving objective (i) and (iii) depend on the realization of objective (ii). In the next section we will illustrate how to realize our goals above.

III. OPTIMAL POWER CONTROL

In this section, we first discuss how to utilize dynamic programming to identify the optimal power values used in simultaneous transmissions. Then, we devise a localized power control algorithm that enables the slot owners to support as many simultaneous transmissions as possible in a given time slot.

A. Problem Formulation and Solution

For a two links simultaneous transmission (link \( l_{12}^1 \) and link \( l_{23}^1 \)), the realization of objective (ii) of the previous section is equivalent to solving the following optimization problem.

\[
\begin{align*}
\min & \sum (P_i^2 + P_i^3) \\
\text{s.t.} & \quad G_i^2 r_i^2 - G_i^3 r_i^3 \geq \gamma(r_i^1) N \\
& \quad G_i^2 r_i^2 P_i^2 + G_i^3 r_i^3 P_i^3 \geq \gamma(r_i^1) N \\
& \quad r_i^1, r_i^2, r_i^3 \in \{r_1, r_2, \cdots r_m\} \\
& \quad r_1 < r_2 < \cdots < r_m \\
& \quad 0 \leq P_i^2 \leq P_{max} \\
& \quad 0 \leq P_i^3 \leq P_{max}
\end{align*}
\]  

(3)

(4)

(5)

(6)

(7)

(8)

(9)

Since \( G_i^2, G_i^3 \), and \( N \) are all constant within the duration of the time slot of interest, if we assign \( r_i^2 \) and \( r_i^3 \) as constant values, then the objective function and all of the constraints represent linear functions. In the following, we will utilize DP to provide our optimal power control algorithm.

To illustrate how to solve our problem as a DP solution, we define a few notations and variables first.

1) Stages and decisions: The essential feature of our proposed DP approach is the structuring of optimization problem into multiple independent steps which are then solved sequentially one step at a time. In our algorithm, we breakdown the procedure of the specification of the powers used by \( n \) simultaneous transmissions into \( n \) steps and select one link’s power at each step. We call each step a “stage” and the power selected in each stage is define as a “decision”. The decision in the \( k \)-th stage is represented by \( x_k \). In our problem, an \( n \)-stage procedure specifies \( n \) optimal powers for \( n \) simultaneous transmission if one exists. Based on the definition above, the problem formulation for a simultaneous transmission over \( n \) links is expressed as follows.

\[
\begin{align*}
\min & \quad (x_1 + x_2 + \cdots + x_n) \\
\text{s.t.} & \quad a_{11} x_1 + \cdots + a_{1k} x_k + \cdots + a_{1n} x_n \geq c_1 \quad (1) \\
& \quad a_{21} x_1 + \cdots + a_{2k} x_k + \cdots + a_{2n} x_n \geq c_2 \quad (2) \\
& \quad \cdots \\
& \quad a_{n1} x_1 + \cdots + a_{nk} x_k + \cdots + a_{nn} x_n \geq c_n \quad (n) \\
& \quad 0 \leq x_1, x_2, \ldots, x_n \leq P_{max}
\end{align*}
\]  

(10)

In the formulation above, \( a_{ik} \) reflects the interference level caused by link \( k \) on link \( i \), \( (a_{ik} < 0 \) when \( i \neq k, a_{ik} > 0 \) when \( i = k) \), \( c_i = N \gamma(r_j^1) \) where \( i \) and \( j \) are the sender and the receiver of link \( i \), respectively. For the simultaneous
transmission over two links formulated by Equation (3), \( a_{11} = G_1^2, a_{12} = -G_3^2 \gamma(r_1^2), a_{21} = -G_1^2 \gamma(r_3^2), a_{22} = G_3^2, c_1 = N \gamma(r_1^2), c_2 = N \gamma(r_3^2) \). We note that in the coefficient \( a_{ik}, i \) represents the the number of the constraints and \( k \) represents the number of stages.

2) State at a stage: Associated with each stage of the optimization problem is the constraint of the stage that the decision has to comply with. At stage \( k \) where \( k \leq n \), we consider all factors except \( a_{ik}x_k \) in constraint \( i \) with \( i \leq k \). We note that only the first \( k \) constrains are to be compiled with. Denoting by \( R_{ik} \) the right hand side of an individual constraint, we define all of the right hand sides of the \( k \) constrains together as “state” \( S_k \) at stage \( k \). Then,

\[
S_k = (R_{1k}, R_{2k}, \ldots, R_{ik}, \ldots, R_{kk})
\]

(11)

The constraint on \( x_k \) at stage \( k \) is \( x_k \in S_k \) and is expressed as shown below.

\[
a_{ik}x_k \geq R_{ik}, \quad (i = 1, 2, \ldots, k)
\]

(12)

The state transition function is as follows.

\[
R_{ik} = R_{i,k-1} - a_{i,k-1}x_{k-1}, \quad (i = 1, 2, \ldots, k)
\]

(13)

3) Optimal objective function: In our algorithm, we take the backward DP approach and define \( f_k(S_k) \) to represent the minimum sum of the powers selected by the stages from \( k \) to \( n \). We refer to the corresponding optimum decision of \( x_k \) as \( x_k^* \). Then, the optimal objective function can be shown as below.

\[
\begin{align*}
  f_k(S_k) &= \min_{x_k \in S_k} \{ x_k + f_{k+1}(S_{k+1}) \}, (k \leq n) \\
  f_{n+1}(S_{n+1}) &= 0
\end{align*}
\]

(14)

In the following, we take the simultaneous transmission problem over two links formulated by (3) as an example, and show the process of specifying the optimal powers. For \( n = 2 \), the optimal objective function is shown as follows.

\[
\begin{align*}
  f_k(S_k) &= \min_{x_k \in S_k} \{ x_k + f_{k+1}(S_{k+1}) \}, (k \leq 2) \\
  f_3(S_3) &= 0
\end{align*}
\]

(15)

When \( k = 2 \),

\[
\begin{align*}
f_2(S_2) &= \min_{x_2 \in S_2} \{ x_2 + f_3(S_3) \} \\
&= \min_{x_2 \in S_2} \{ x_2 \} \\
&= \min_{\frac{a_{22}}{a_{22}} \leq x_2 \leq \frac{a_{22}}{|a_{12}|}} \{ x_2 \} \\
&= \min_{\frac{a_{22}}{|a_{12}|}} \{ x_2 \}
\end{align*}
\]

(16)

When \( k = 1 \),

\[
\begin{align*}
f_1(S_1) &= \min_{x_1} \{ x_1 + f_2(S_2) \} \\
&= \min_{\frac{a_{11}}{|a_{11}|} \leq x_1 \leq P_{max}} \{ x_1 + \min(\frac{a_{21} - a_{22}}{|a_{12}|}) \} \\
&= \min_{\frac{a_{11}}{|a_{11}|} \leq x_1 \leq P_{max}} \{ x_1 + \min(\frac{a_{21} - a_{22}}{|a_{12}|}, \frac{a_{11}x_1 - R_{12}}{|a_{12}|}) \} \\
&= \min_{\frac{a_{11}}{|a_{11}|} \leq x_1 \leq P_{max}} \{ x_1 + \min(\frac{N \gamma(r_3^2) + G_1^2 \gamma(r_3^2)x_1}{G_3^2} - \frac{G_3^2 x_1 - N \gamma(r_3^2)}{G_3^2 \gamma(r_3^2)}) \}
\end{align*}
\]

(17)

We can see that the value of (17) decreases as the value of \( x_1 \) decreases. From a mathematical point of view, the minimum value of (17) is reached at point \( x_1 = \frac{N \gamma(r_3^2)}{G_3^2} \) which means that the power selected by the slot owner can support its own transmission only. Obviously, this kind of value for \( x_1 \) is not what we seek. What we want is the value of \( x_1 \) under which the two links can transmit simultaneously. Hence, the selection of \( x_1 \) has to allow for selecting at least one value that can support the transmission over \( b_3 \).

\[
\min(\frac{N \gamma(r_3^2) + G_1^2 \gamma(r_3^2)x_1}{G_3^2} - \frac{G_3^2 x_1 - N \gamma(r_3^2)}{G_3^2 \gamma(r_3^2)})
\]

(18)

Obviously, the value of (18) decreases as the value of \( x_1 \) decreases and the smallest value is achieved when the upper bound is equal to the lower bound.

\[
\frac{N \gamma(r_3^2) + G_1^2 \gamma(r_3^2)x_1}{G_3^2} = \frac{G_3^2 x_1 - N \gamma(r_3^2)}{G_3^2 \gamma(r_3^2)}
\]

(19)

Then, we get the optimal value of \( x_1 \) as shown below.

\[
x_1^* = \frac{G_3^2 N \gamma(r_3^2)}{G_3^2 G_3^2 - G_3^2 G_1^2 \gamma(r_3^2) \gamma(r_3^2)}
\]

(20)

We note that \( x_1^* \) satisfies the conditions of an “apex solution” to the problem described in [10] and thus represents the minimum power that can be used by \( b_3 \). It is also worth noting that the optimal value of \( x_1^* \) at stage 2 of backward recursion and the optimal decision of stage 2 constitute the optimal decision when we consider stage 1 and stage 2 together. This means that our solution complies with the basis of recursive optimization procedure in dynamic programming [20]. Entering \( x_1^* \) in (16) we get,

\[
x_2^* = \frac{N \gamma(r_3^2) + G_1^2 \gamma(r_3^2)x_1^*}{G_3^2} = \frac{G_1^2 N \gamma(r_3^2) + G_1^2 N \gamma(r_3^2) \gamma(r_3^2)}{G_1^2 G_3^2 - G_3^2 G_1^2 \gamma(r_3^2) \gamma(r_3^2)}
\]

(21)

Similarly, \( x_2^* \) is the minimum power that can be used by \( b_3 \). If \( 0 \leq x_1^*, x_2^* \leq P_{max} \) and \( b_3 \) can transmit simultaneously with rates \( r_2^* \) and \( r_3^* \), respectively. We note that the computational complexity of the algorithm is only quadratic in terms of the number of links requiring to transmit.

Following the same process as the one for treating two simultaneous transmissions, the case of an arbitrary number of simultaneous transmissions can be solved using dynamic programming. Due to shortage of space, we do not provide the details in this paper.
B. Optimal Power Control Algorithm

In this section, we elaborate on the details of our power control algorithm. Our algorithm works on specified time slot assignment strategies and is to be executed at the beginning of each time slot. We take DTSA for example here. DTSA is a slot assignment strategy designed for TDMA based ad-hoc networks. It can guarantee no pair of nodes within a two-hop neighborhood are assigned to the same slot. We embed two kinds of control packets into DTSA and call them Transmit Requirement Packet (TRP) and Power Information Packet (PIP).

- TRPs are transmitted to the slot owner at the beginning of a slot by the nodes which are not the current slot owner but would like to transmit within that slot. By sending a TRP to the slot owner, a node informs the slot owner about the position of the sender and the receiver. The traffic load of the link should be contained in the TRP.
- PIPs are transmitted by the slot owner to inform the calculated powers and rates to the nodes which are permitted to transmit.

At the beginning of the slot, every node within the LCA of the slot owner and interested in transmission sets a random timer. As the timer goes off, the associated node sends a TRP to inform its intent to transmit to the slot owner. To gather this information, the slot owner listens on a control channel for transmission requests from the neighbors for a certain short period of time referred to as \( \tau \). The listening period \( \tau \) is typically set to the first 7% to 10% of the slot duration. In order to prevent the collision of TRPs, the random timer \( r_i \) at node \( i \) is set as follows:

\[
\tau > r_i = t_0 + 0.07T + r, \quad 0 \leq r \leq 0.03T
\]  

(22)

where \( t_0 \) represents the beginning of a time slot, \( T \) is the length of the time slot, and \( r \) is a number selected randomly. The slot owner will grant permissions to transmit on a first-come first-serve basis. Upon the receipt of a TRP, the slot owner begins to evaluate whether a node can be granted permission to simultaneously transmit in its slot. If two simultaneous transmissions can be established, the slot owner evaluates whether a third transmission can be permitted upon the receipt of a second request. If the first request could not be granted, the slot owner still evaluates the possibility of granting permission to transmit in response to the second request independent of the first request. The process continues this way, i.e., upon the receipt of a new request within the period of \( \tau \). The slot owner assigns data rates as follows. First, it assigns itself the highest rate possible, not to exceed the rate that can finish its transmission within that slot. For the other links, it searches from the highest to the lowest data rates until to find the rate that can establish a simultaneous transmission. If the slot owner has no packet to transmit, the first request will receive the highest priority, but the slot owner is still responsible for evaluating the requests and granting permissions to transmit. The slot owner will stop evaluating transmission requests, hand out the results of evaluations through broadcast PIPs to its neighbors, and begin transmitting. The other nodes granted permission to transmit will begin transmitting after receiving notification from the slot owner using the optimal transmission powers and the data rates as dictated by the slot owner. Our optimal power control algorithm at a given slot is described below.

Algorithm 1: Optimal Power Control Algorithm

1: The time slot assignment policy and clock synchronization are initialized as the initial step of operating the protocol.
2: At the beginning of a slot, the slot owner collects the TRPs from neighboring nodes in its LCA.
3: The slot owner endows every request a priority according to its time of arrival and calculates the optimal powers using dynamic programming according to the priority.
4: The slot owner hands out the PIPs at the end of period of \( \tau \) or all collected TRPs and begins transmitting.
5: The other nodes granted permission in the LCA begin to transmit with a data rate dictated by the slot owner.

From the description of the algorithm, it is observed that the computational complexity is specified by step 3. If there are a total of \( L \) active links in the slot owner’s LCA, the computational complexity of the algorithm is in the order of \( O(L^2) \) which is the same magnitude of DPRL. This low computational complexity is important for us to achieve realization of objective (i) and objective (iii) mentioned in section II. In the next section, our simulation results show that the number of simultaneous transmissions is most closely tied to the relative position of the transmitting nodes and the corresponding receivers.

IV. Experimental Analysis

To study the performance effects of our OPC algorithm on STDMA MAC protocols, we carry out numerical experiments in NS3. We embed the OPC algorithm into DTSA but refer to it as OPC for brevity. We use DTSA as a non-STDMA and DPRL as an STDMA benchmark for evaluating the performance of our algorithm. In our experiments, the network topology consists of 100 stationary nodes independently and uniformly distributed in a square area with dimensions of \( 400 \times 400 \) square meters. The value of \( P_{\text{max}} \) is set to 30 dBm and the average thermal noise power \( N \) is \(-50\) dBm. We examine 5 different scenarios by selecting distinct path loss exponents, i.e., \( \theta \) in Equation (2). The latter means that our network operates in 5 different environments ranging from line of sight free space to indoor environments. The path loss exponent impacts the maximum transmission range under different rates and influences the slot assignment strategy of DTSA and the performance of our algorithm. A higher value of \( \theta \) means a higher spatial reuse factor and can represent a different network density. Our simulation program randomly selects 30 links formed by this 100 nodes on which messages can be exchanged at the lowest rate under all path loss exponents. For our algorithm, each link can pick one out of
five transmission rates all expressed with packets per slot unit from the set \( \{ r_1 = 1, r_2 = 3, r_3 = 5, r_4 = 7, r_5 = 9 \} \). We use Shannon’s channel capacity formula to calculate the corresponding SINR threshold at different rates. The farthest transmit ranges corresponding to different rates for different value of \( \theta \) are shown in Table I. Data rates are assigned based on the parameter settings of the table. In what follows, we assume each DTSA link uses the highest achievable data rate and the lowest power satisfying the corresponding SINR constrains. The slot length is 30 ms and the operation duration of OPC algorithm is set to 3 ms.

To test the performance of OPC under high traffic loads, we first compare the performance of OPC with that of original DTSA and DPRL in a saturated network operating scenario in which all nodes have traffic to transmit at any time. Considering different values of path loss exponent \( \theta \), Fig. 1 shows the network throughput attained under DTSA augmented by the OPC algorithm, standard DTSA, and DPRL. The reported results are the averages associated with 50 simulation runs of thirty minutes or longer. As can be seen, the performance of the three algorithms are almost the same for \( \theta = 2 \). That is because high interference renders simultaneous transmissions nearly impossible for small values of \( \theta \). As \( \theta \) grows to values greater than 2.5, the throughput under OPC and DPRL are both more than twice higher than that attained by DTSA since multiple simultaneous transmissions are possible. At the same time, OPC is outperforming DPRL since optimal power values decrease interference thereby allowing for more simultaneous transmissions compared to DPRL. Noticeable performance improvements are realized under OPC and DPRL as \( \theta \) varies in the range of 3.5 to 4 since a larger number of links can share the same slot with the increase of \( \theta \). For this range, the use of OPC and DPRL can result in having simultaneous transmissions in up to 4 LCAs. Fig. 2 shows the average PER corresponding to Fig. 1. Since increasing spatial reuse results in increasing interference from nodes both inside and outside of the LCA, the general trend of all the algorithms are increasing. Due to interference caused by simultaneous transmissions, the PER of DPRL and OPC are higher than that of DTSA. Even though, the packet loss rate of OPC is acceptable and do not lower the throughput significantly. Fig. 3 depicts the average power consumption of transmitting one packet. It is observed that the power consumption of OPC algorithm remains a little higher than that of DTSA in all scenarios. That is because although OPC minimizes the interference between simultaneous transmissions, it does not completely eliminate interference. At the same time, the power consumption of DPRL is much higher than that of OPC. This corresponds to the fact that DPRL uses very high powers in order to achieve high data rates thereby significantly increasing mutual interference.

To evaluate the performance of OPC under light traffic loads, we run another set of simulations in which we compare the performance of the same three algorithms. In each experiment, we assume that each one of the randomly selected 30 nodes has 100 packets that need to be transmitted. In the case of each algorithm, we transmit all of the packets. Then, we record the completion time and calculate the corresponding throughput, PER and power consumption. As illustrated by Fig. 4, the most significant difference in each scenario is that the gap of the throughput performance between DTSA and OPC is much higher than that attained under the saturated.

### Table I: Transmission ranges calculated by Shannon’s channel capacity formula.

<table>
<thead>
<tr>
<th>( C )</th>
<th>( \text{SINR}_{\text{threshold}} )</th>
<th>( d_{\text{max}}(\theta = 2) )</th>
<th>( d_{\text{max}}(\theta = 2.5) )</th>
<th>( d_{\text{max}}(\theta = 3) )</th>
<th>( d_{\text{max}}(\theta = 3.5) )</th>
<th>( d_{\text{max}}(\theta = 4) )</th>
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<td>193</td>
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network. That is because when the network is non-saturated, DTSA wastes a lot of idle slots. To the contrary, not only OPC uses the idle slots but also establishes multiple simultaneous transmissions in those slots. Fig. 5 shows the average PER performance corresponding to Fig. 4. The most notable observation is that the gaps between OPC and the other two algorithms are much lower than those in saturated networks. This is due to mutual interference decrease associated with decreasing simultaneous transmissions in the same slot. From Fig. 6, we can see that the most significant difference in each scenario is that the gaps between the power consumption of OPC and DPRL are higher compared to the saturation experiments. This is because at low transmit rates, OPC assigns each link the corresponding optimal power and therefore the consumption of energy is low but DPRL still uses high powers and the consumption of energy is high.

V. Conclusion

In this paper, we proposed a practical power control algorithm as a generic time slot assignment STDMA strategy capable of generating optimal simultaneous transmission schedules. Our low complexity dynamic programming algorithm minimized transmission powers under rate driven SINR constrains. We compared the performance of our proposed algorithm to that of original DTSA and DPRL algorithms and showed that our power control algorithm is able to perform well under different traffic loads and types. Currently, we are in process of extending our work to offer priority mechanisms beyond random choices of accommodating transmitting nodes and capture the effects of high impact mobility.

References