that $p_{\text{D}^{-}\text{min}}$ represents how $D_{\text{min}}$ is close to the distance at which outage occurs with probability equal to unity. Hence, as $p_{\text{D}^{-}\text{min}}$ decreases RAP-MAC tends to be more conservative (i.e., lower $p$ and $q$ values) in order not to violate the PRN constraints. However, as $\beta$ increases, the impact of $p_{\text{D}^{-}\text{min}}$ on the optimal values of $p$ and $q$ is reduced. As shown in Figure 3, $p$ and $q$ fall slowly for $\beta = 5\%$ and $10\%$. Note that, the PRN activity factor only impacts the value of $q$ (but not $p$) as explained earlier regardless the value $\beta$. However, the impact of the PRN activity factor on $q$ increases with the relaxation of the PRN constraint $\beta$ as shown in Figure 3(b).

**CRN User Rate.** Despite the strong dependencies of the optimal value of $p$ and $q$ on $p_{\text{D}^{-}\text{min}}$, Figure 4(a) shows that $p_{\text{D}^{-}\text{min}}$ has minimal impact on the maximum rate of CRN users. While the closer $p_{\text{D}^{-}\text{min}}$ to $1 - \beta$ achieves the highest CRN rate, using smaller values for $p_{\text{D}^{-}\text{min}}$ achieves very close CRN rate. For example, the CRN rate using $p_{\text{D}^{-}\text{min}} = 0.94$ is only 1% to 2.8% (depending on the PRN activity factor) less than the rate when $p_{\text{D}^{-}\text{min}} = 0.95$. Note that the CRN rate deteriorates with the increase of the PRN activity. Meanwhile, using $p_{\text{D}^{-}\text{min}} = 0.94$ in stead of 0.95 changes $p$ from 0.833 to 0.714 which allows bigger probabilistic capacity margin for multiple SUs to share available opportunities. Similar results were obtained for other values of $\beta$. Figure 4(b) depicts the loss in the CRN user rate versus the offset in $p_{\text{D}^{-}\text{min}}$ from its maximum value of $1 - \beta$ for different values of $\beta$ and $\alpha$. The deterioration in the CRN user rate with $p_{\text{D}^{-}\text{min}}$ increases as the PRN constraint $\beta$ gets tighter and the PRN activity factor $\alpha$ increases.

**V. RAP-MAC PERFORMANCE EVALUATION**

In this section, we evaluate the performance of the RAP-MAC protocol. We develop an event-driven packet-level simulator. We consider 9 PRNs collocated with a CRN in a $500 \times 500$ square meter area. Each network has 200 nodes forming 100 sender-receiver pairs. The operating frequencies of the 9 PRNs are $\{0.769, 0.789, 0.809, 2.412, 2.432, 2.462, 5.180, 5.200, 5.220\}$ GHz with respective activity factors of $\{0.1, 0.5, 0.9, 0.1, 0.5, 0.9, 0.1, 0.5, 0.9\}$. The bandwidth of each channel is 20 MHz and the power mask is 2 nW for all PRNs. The PRN transmit power is 1 W and the transmit and receive antenna gains are equal to unity for all PRNs. We consider PRN maximum allowed outage probability values of 1%, 5%, and 10%. The path loss exponent $n$ is set to be 4. A secondary transmission can use a rate in the set $\{54, 36, 24, 12, 2\}$ Mbps. The corresponding set of transmission powers is calculated according to (1) with the transmission power of the 54 Mbps rate is equal to 1 W. We vary the arrival rate of all CRN users from 1 Mbps to 35 Mbps. For each arrival rate value, we generate 10 random node topologies. For each