topology, we generate 3 traffic matrices. The reported results are the average of these 30 runs for each arrival rate value. The error bars represent the 95% confidence interval of the multiple runs. We use (22) to compute the optimal values of \( p \) and \( q \) for different values of \( \beta \).

Our benchmark is a protocol that belongs to the family of hypothetically-optimal spectrum access protocols which has a wide-sense capability and a greedy spectrum approach in the sense that a SU-TX exploits the best spectral opportunity at the maximum permissible power/rate. We use [16] to compute such maximum powers/rates. In order to insure fairness in comparison, we do not implement the capability of a secondary user to simultaneously transmit over multiple spectrum bands at a given time instant as in the protocol presented in [16]. We refer to such a modified protocol as OPT-MAC as it represents a wide range of spectrum access protocols that adopt greedy spectrum access mechanisms for transmission over available spectral opportunities (e.g., [24], [12], [18]). OPT-MAC spectrum access mechanism is carrier-sensing based that uses message exchange over the common control channel to insure a single secondary user transmission per contention area. For each randomly generated topology and arrival process, we run both the RAP-MAC and OPT-MAC protocols to guarantee fairness in comparison. Data packets are 1500 bytes long for both protocols. Control packets of both protocols are 40 bytes transmitted at 12 Mbps rate over the common control channel. Spectrum sensing and transceiver turn-around times are 9 and 5 \( \mu \text{sec} \), respectively. The exponential backoff window is bounded by (16, 1024) slots of 2 \( \mu \text{sec} \) duration. Our performance metrics are the CRN average goodput, Jain’s index as a measure of the fairness in CRN goodput distribution [26], and the outage probability of the PRNs defined as the probability of PRNs transmission failure due to CRN activities.

**CRN Goodput.** Figure 5(a) depicts the average goodput of CRN users using both the RAP-MAC and OPT-MAC for \( \beta \) equals to 5%. RAP-MAC achieves significantly higher goodput compared to OPT-MAC. The RAP-MAC gain in the CRN user goodput varies between 65% and 119.5% depending on the CRN traffic demand. RAP-MAC significant gain in goodput is attributed to: (i) the fact that RAP-MAC probabilistically (with probability \( q \)) explores the spectral opportunities that OPT-MAC does not explore at all when the interference measurements imply unclear opportunities. (ii) RAP-MAC is less susceptible to transmission failures (compared to OPT-MAC) due to its probabilistic non-greedy policy for the clear spectrum situations which allows multiple flows to simultaneously use a given spectrum at highly reliable lower transmission rates. Consequently, the RAP-MAC gain depends on the value of \( \beta \) which affects the optimal values of \( p \) and \( q \) as explained in Section IV. Figure 5(b) depicts the RAP-MAC gain for different \( \beta \) values. As \( \beta \) increases, the gain in the CRN goodput increases up to 138% as the case with \( \beta \) equals to 10%. This is due to the fact that the value of \( q \) obtained using (22) is 0.5, 0.41, and 0.15 for \( \beta \) equals to 10%, 5%, and 1%, respectively. Furthermore, Figure 5(b) shows that the gain peaks at low CRN traffic demands then decreases before it linearly increases with the traffic demands at \( \beta \) equals to 5% and 10%. For instance maximum gain of 119.5% and 138% are achieved at 5 Mbps and 7.5 Mbps for \( \beta \) equals to 5% and 10%, respectively. However, the RAP-MAC goodput gain decreases before increasing again for the more stringent outage constraint of \( \beta \) equals to 1%.

As we mentioned earlier, the superior goodput performance of RAP-MAC is due to the bigger gap between its transmission attempts and transmission blockage (due to either PRN or CRN activities) compared to OPT-MAC as shown in Figure 6(a) for \( \beta \) equals to 5%. As \( \beta \) increases, the gap between the blocked and attempted transmissions increases. Regardless the value of \( \beta \), the number of transmission attempts of RAP-MAC (the solid circled line) is only slightly higher than that of OPT-MAC (the solid circled line). However, OPT-MAC transmissions are susceptible to more blockages as it does not account for the activities of hidden PRN or CRN nodes (the dashed lines). Recall that OPT-MAC either allows a CRN sender to transmit at the highest possible power/rate or to not transmit at all. Meanwhile, RAP-MAC has a secondary flow probabilistically adapt its power/rate based on the interference scenario. Figure 6(b) depicts the distribution of the rates used by RAP-MAC under low and high CRN traffic demands. At high CRN demand, RAP-MAC tends to have the CRN flows using the minimum rate more often to allow multiple CRN flows to simultaneously share spectral opportunities. As