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# Multi-user rate and power analysis in a cognitive radio network with massive multi-input multi-output

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**Key words:** Massive multi-input multi-output; Cognitive radio ; Relay network; Transmission rate; Power analysis

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# Motivations

1. In recent years, the spectrum scarcity generated by the evolution of wireless technologies has led us to rethink traditional transmission strategies.

2. Cognitive radio (CR) is considered as a promising solution to this dilemma. Secondary user (SU) networks can coexist with primary user (PU) networks through opportunistic spectrum access, providing that the SU does not adversely affect the PUs' performance.

3. Massive multi-input multi-output (MIMO) is regarded as the promising technology for meeting the huge capacity needs for 5$^{th}$ generation (5G) cellular networks.

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# Main ideas

1. When the ratio between the base station (BS) antennas and relay antennas becomes large enough, the transmission performance of the whole system is independent of the BS-to-relay channel parameters, and is only related to the relay-to-users process.

2. When the ratio between the primary base station (PBS) antennas and relay antennas becomes infinite, the asymptotic sum rate equals half the rate of a single-hop single-antenna $K$-user system without fast fading.

3. The interference between the primary network and secondary network can be asymptotically mitigated. The transmission performance of the primary and secondary networks do not contain the interference temperature. The secondary network can use peak power to transmit information without causing any interference to the primary.

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# Methods

1. Signal transmit theory and law of large numbers are performed to derive the closed expression solution:

   (1) The downlink transmission performance of a relay-aided massive MIMO network without CR is discussed. By using the power distribution criteria, the $k^{th}$ user's asymptotic SINR is independent of fast fading.

   (2) In the underlay CR network with massive MIMO, the cognitive transmission performances of PUs and SUs under perfect channel state information (CSI) and imperfect CSI are derived, including the end-to-end SINR and achievable sum rate.

2. Using game theory to derive the PUs' utility function that relates to the sum rate and relay power in the underlay CR network is defined. The optimal relay power is derived to maximize the utility function.

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# Major results

1. As the ratio grows, the asymptotic sum rate increases. When the ratio between the base station antenna number and relay antenna number becomes large enough, there is a limit.

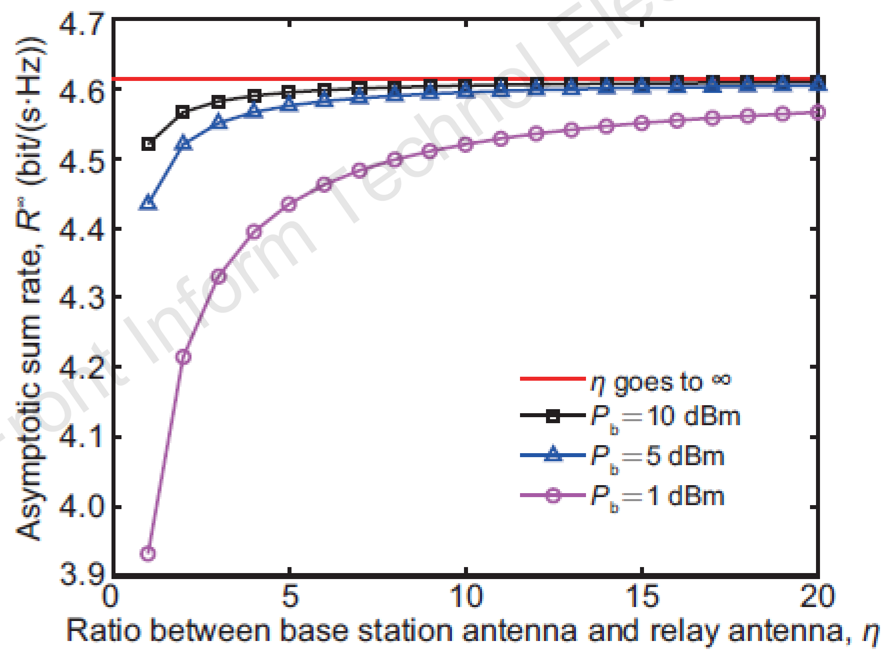


**Fig. 5 Asymptotic sum rate versus the antenna ratio for $K$=2 and $E_{\mathrm{R}}$=100 dBm in the massive multi-input multi-output relay network**

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# Major results

2. As the number of primary base station antennas grows, the sum rates of the primary users and secondary user in this practical scenario tend to the theoretical analysis. The secondary user asymptotic theoretical analysis has no relationship with the primary network parameters, such as *K* and interference temperature.

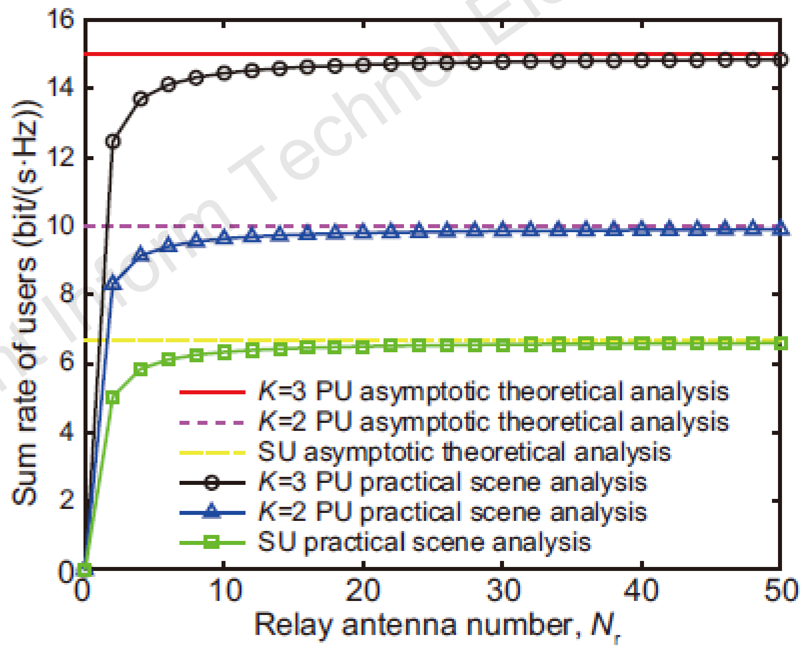


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**Fig. 6** Sum rate of users versus the relay antenna number in the relay underlay cognitive radio network with massive multi-input multi-output

# Major results

3. Therefore, as the relay power grows, the utility function increases first and then decreases.

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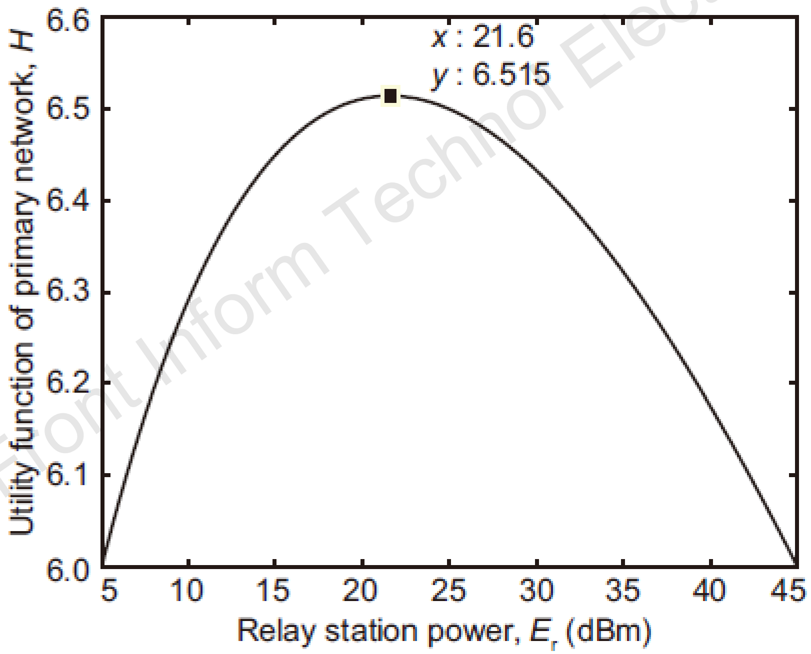


**Fig. 9 Primary users' utility function versus relay power in the relay underlay cognitive radio network with massive multi-input multi-output**

# Conclusions

1. When the PBS antennas, SBS antennas, and relay antennas became infinite, the asymptotic SINR was independent of fast fading. The interference between the primary network and secondary network was asymptotically canceled. The transmission performance did not include the interference temperature. The secondary network could use its peak power to transmit without causing any interference to the primary network.

2. The PUs' utility function was defined based on the relay power and asymptotic SINR of PUs. The utility function was maximized by optimizing the relay power.

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