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Pretty good state transfer on double stars

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Let A be the adjacency matrix of a graph X and suppose U(t)=exp(itA). We view A as acting on $\cx^{V(X)}$ and take the standard basis of this space to be the vectors e_u for u in $V(X)$. Physicists say that we have perfect state transfer from vertex u to v at time τ if there is a scalar γ such that $U(\tau)e_u = \gamma e_v$. (Since $U(t)$ is unitary, $\norm\gamma=1$.) For example, if X is the d-cube and u and v are at distance d then we have perfect state transfer from u to v at time $\pi/2$. Despite the existence of this nice family, it has become clear that perfect state transfer is rare. Hence we consider a relaxation: we say that we have pretty good state transfer from u to v if there is a complex number γ and, for each positive real ϵ there is a time t such that $\norm{U(t)e_u - \gamma e_v} < \epsilon$. Again we necessarily have $|\gamma|=1$.
Godsil, Kirkland, Severini and Smith showed that we have have pretty good state transfer between the end vertices of the path P_n if and only $n+1$ is a power of two, a prime, or twice a prime. (There is perfect state transfer between the end vertices only for P_2 and P_3.) It is something of a surprise that the occurrence of pretty good state transfer is characterized by a number-theoretic condition. In this paper we study double-star graphs, which are trees with two vertices of degree $k+1$ and all other vertices with degree one. We prove that there is never perfect state transfer between the two vertices of degree $k+1$, and that there is pretty good state transfer between them if and only if $4k+1$ is a perfect square.

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