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*When do subsets of $\{0,1\}^{G\times G}$ contain recurrent points?*

Suppose $G$ is a (countable) group and $C$ is a closed, nonempty, $G$-invariant subset of $\{0,1\}^{G\times G}$. For an application in the theory of orderable groups, we would like to know there exists a point $c \in C$, such that $c$ is recurrent for the action of each $T \in G$.

The Poincaré Recurrence Theorem implies this is the case when there is a $G$-invariant probability measure on $C$, so $c$ always exists if $G$ is abelian, or, more generally, if $G$ is amenable. For what other classes of groups does such a point $c$ always exist? In particular, does it suffice to assume that $G$ has no nonabelian free subgroups?