Impact of Interferences on Connectivity in Ad Hoc Networks

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Model

- The position of the nodes is a Poisson point process in $\mathbb{R}^2$.
- Node $i$ emits with power $P_i$.
- Isotropic attenuation function $l(d)$ where $d$ is the distance.
- Node $i$ can receive data from Node $j$ iff:
  \[ \frac{P_j l(||x_j - x_i||)}{N_0 + \gamma \sum_{j \neq i} P_j l(||x_k - x_i||)} \geq \beta \]

Properties:

- The sum $\sum_{j \neq i} P_j l(||x_k - x_i||)$ (which is a Poisson shot-noise process) is a.s. finite $\forall x$ iff $\int^y_0 t l(t) dt < \infty$ for some $y$.
- If $\gamma > 0$, the node degree is bounded to $1 + \lfloor 1 / \beta \gamma \rfloor$.

Effect of interferences

Interferences mostly destroy links in very populated regions.

Percolation

We proved the following:

1. Percolation threshold for $\gamma = 0$
   When $\gamma = 0$, the model is a Boolean model and therefore percolation occurs if the nodes density $\lambda$ is above a certain threshold $\lambda^*(0)$.

2. Existence of percolation for small values of $\gamma$
   If $\gamma$ is sufficiently small, there exists $\lambda^*(\gamma) < \infty$ such that if the density $\lambda > \lambda^*(\gamma)$ percolation occurs.

3. Non-existence of percolation for large values of $\gamma$
   If $\gamma > 1 / \beta$, percolation never occurs, regardless of the node density. In fact, the node degree is limited to 1 in this case.

4. Critical density is an increasing function of $\gamma$
   If the interferences are stronger ($\gamma' > \gamma$), the percolation threshold is higher ($\lambda^*(\gamma') > \lambda^*(\gamma)$).

Conclusion

- The node degree is bounded whenever $\gamma > 0$.
- However, percolation is still possible if $\gamma$ is sufficiently small.
- A simple $n$-slots TDMA scheme is equivalent to (and even better than) reducing the interferences by a factor $n$.

TDMA approach

- $\gamma$ must be small to allow percolation (i.e., long-range connectivity). What can make $\gamma$ smaller than one?
- CDMA allows to reduce $\gamma$, but it is very difficult to implement in ad-hoc networks
- a simple TDMA scheme permits to restore percolation:
  Each node chooses randomly a label between 1 and $n$. During Time Slot $i$, $i \in \{1, \ldots, n\}$, only nodes with Label $i$ are allowed to emit.

We compared by simulation this scheme with the case where all nodes emit at the same time and $\gamma$ is $n$ times smaller.