Problem 1:

Lemma 1:

Objective: Establishment of end-to-end connectivity.
Connectivity is associated to coverage: it is geometrically proven that sensing coverage can ensure connectivity, if the sensing coverage radius is at least equal to half of the network transmission radius. In the general case:
The connectivity problem is associated to the calculation of the critical transmission range. Minimum transmission power is not the optimal solution from a macroscopic, power-aware point of view. However, determining the optimal transmission range remains essential, as the lower bound, upon which end-to-end connectivity is guaranteed.
The end-to-end connectivity problem is herein approached as a proximity problem (Computational Geometry, Delaunay Tessellation): Sufficient conditions for establishing end-to-end connectivity based on the Delaunay tessellation are provided and exploited for constructing the Distributed Delaunay Connectivity Algorithm.

Strengths:
- No network overhead: no need for special message transmission
- Distributed Delaunay Connectivity Algorithm converges in quadratic time
- Small gap among sub-optimal and optimal solutions.

Weaknesses:
- Sub-optimality (approximation algorithms)
- A-priori awareness of local Delaunay edges

Distributed End-to-End Connectivity based on Delaunay Awareness

End-to-end connectivity condition:

Each node calculates locally the optimal path and transmission power for establishing end-to-end connectivity with its Delaunay neighbours. The final value of the transmission power for each node is the one that guarantees connectivity with all Delaunay neighbours over Delaunay edges.

Simulation Studies

Simulation Snapshot: \( G_N = 104 \)

(A) Operation at minimum transmission power: End-to-end connectivity is not achieved.

(B) Operation at maximum transmission power: End-to-end connectivity is achieved, with the cost of extraordinary edges.

(C) Operation based on MST: End-to-end connectivity is achieved. Optimal solution, based on centralized knowledge.

(D) Operation based on Distributed Delaunay Connectivity: End-to-end connectivity is achieved. Sub-optimal (w.r.t. MST). Derived based on local Delaunay awareness. Redundant edges are reduced.

Simulation Results

Power Consumption & Lifetime

End-to-End Connectivity

The proposed scheme offers same end-to-end connectivity as the one provided by the operation at the maximum transmission power, with less redundant edges. As the network size increases the proposed scheme converges to a planar graph (as the MST is).

Power Consumption and Lifetime

Significant improvement in both power consumption and lifetime, w.r.t. the network's operation in maximum transmission power. Despite its suboptimality, the proposed scheme follows the behavior of the MST (optimal solution), and both power consumption and lifetime converge to the same level as the network size increases.

100% increase to transmission and reception rate does not significantly affect the power consumption and lifetime during the operation of the network based on the proposed scheme.