Bootstrapping Node Localization through Physical Layer Network Coding in Wireless Networks

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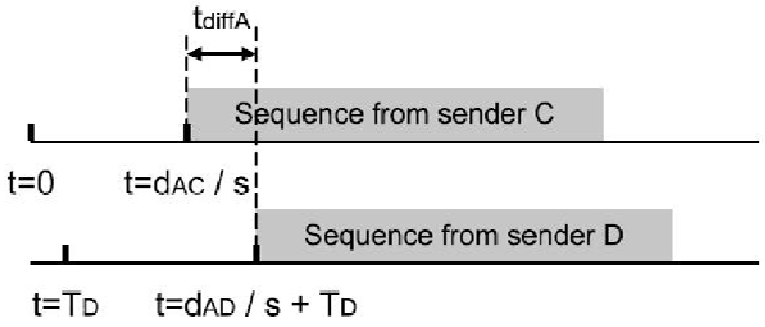
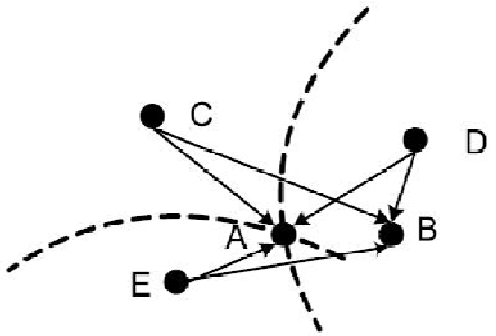
- Research motivation
  - PNC based localization was first presented in 2010
  - Many important problems left untouched
    - Bootstrapping procedures
    - Robustness to malicious attacks
    - Localization accuracy
  - Answers to these questions will
    - Promote further study of PNC technique
    - Determine the network scenarios that can adopt the approach

- PNC based localization
  - Anchor nodes send out signal sequences
  - Using the interference results at the wireless nodes to determine hyperbolas
  - The node is located at the intersection of the hyperbolas





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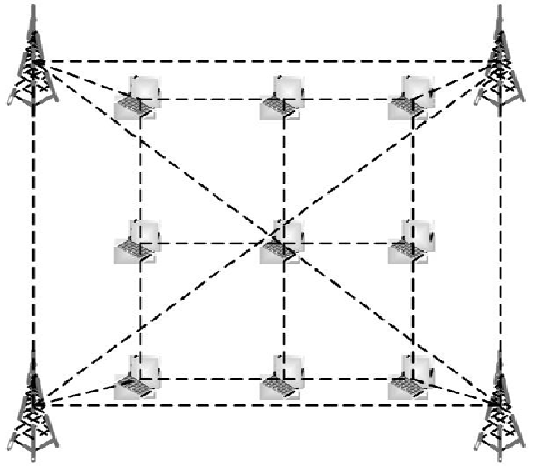
- Desirable properties of PNC based localization
  - Do not need synchronization among wireless nodes
  - Senders do not have to synchronize their transmission operations
  - Do not need special hardware equipments, reduced node cost
  - Scalable, self-organized approach

- Bootstrapping in Wireless Networks with Infrastructures
  - Use the special nodes such as the access points or cellular phone towers as anchors
  - Signals from the anchors can cover large areas of wireless networks
  - The same interference sequences can help many nodes to determine their positions



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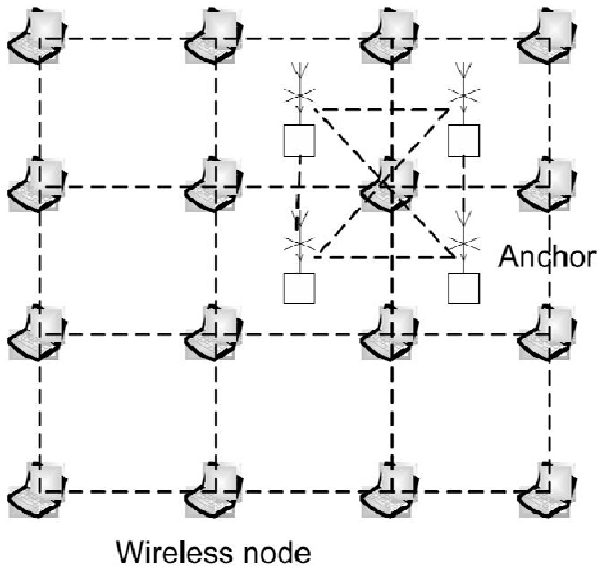
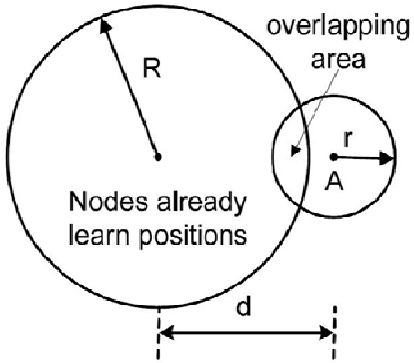
- Bootstrapping in self-organized networks
  - Use a small group of anchors to bootstrap the localization procedures
  - The nodes already learning their positions can serve as anchor nodes for other devices
  - The localization procedure will propagate as a growing circle



- How can we make sure the localization procedure can propagate throughout the network?
  - The number of neighbors that have been positioned



$$S_{overlap} = r^2 \cos^{-1}\left(\frac{d^2 + r^2 - R^2}{2dr}\right) + R^2 \cos^{-1}\left(\frac{d^2 + R^2 - r^2}{2dR}\right) - \frac{1}{2}\sqrt{(-d + r + R)(d + r - R)(d - r + R)(d + r + R)}$$

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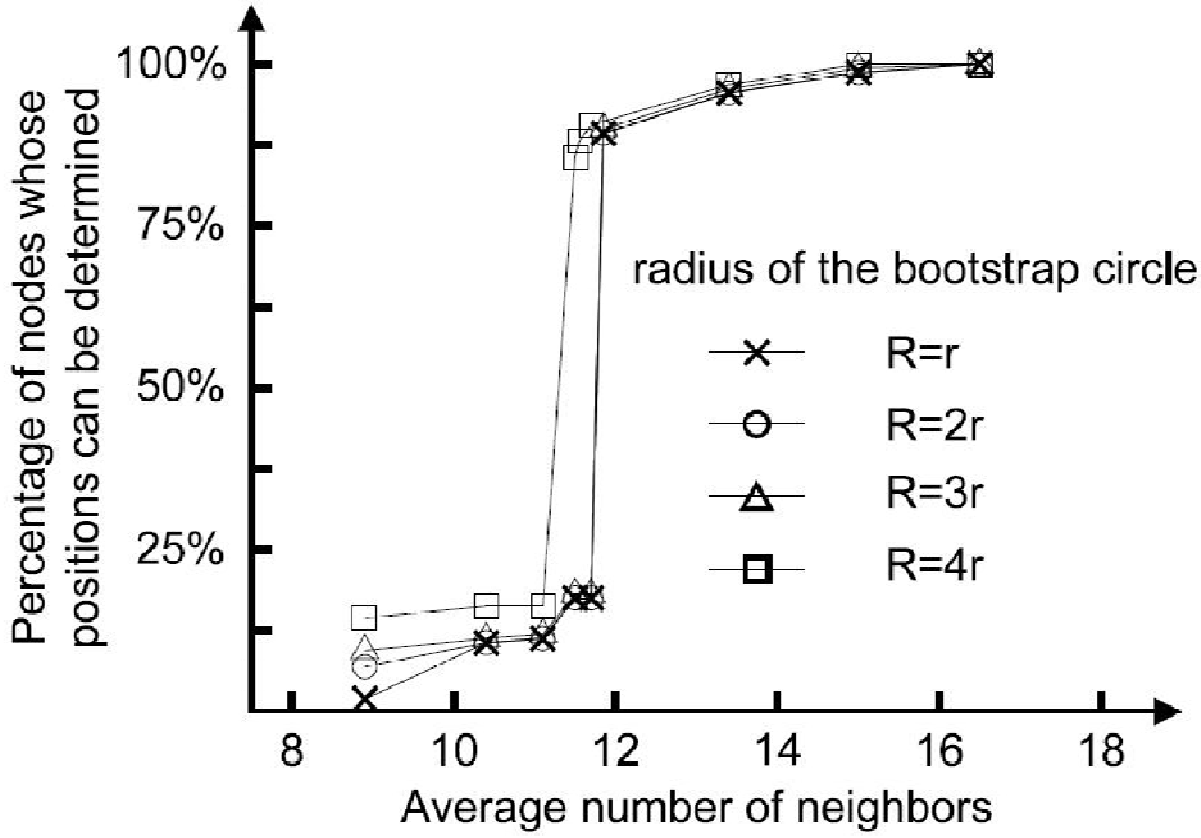
- The size of the overlapping area

$$\mathrm{E}(S_{overlap}) = \frac{\int_{R}^{r+R} S_{overlap} \times 2\pi x \mathrm{d}x}{\pi(R+r)^2 - \pi R^2}$$

- When $R = r, E(S_{Overlap}) = \frac{\sqrt{3}}{4} r^2$
- When $R = \infty, E(S_{Overlap}) = \frac{2}{3} r^2$
- The required average degree of connectivity falls into the range [14, 22]

- Impacts of node density and size of bootstrap area



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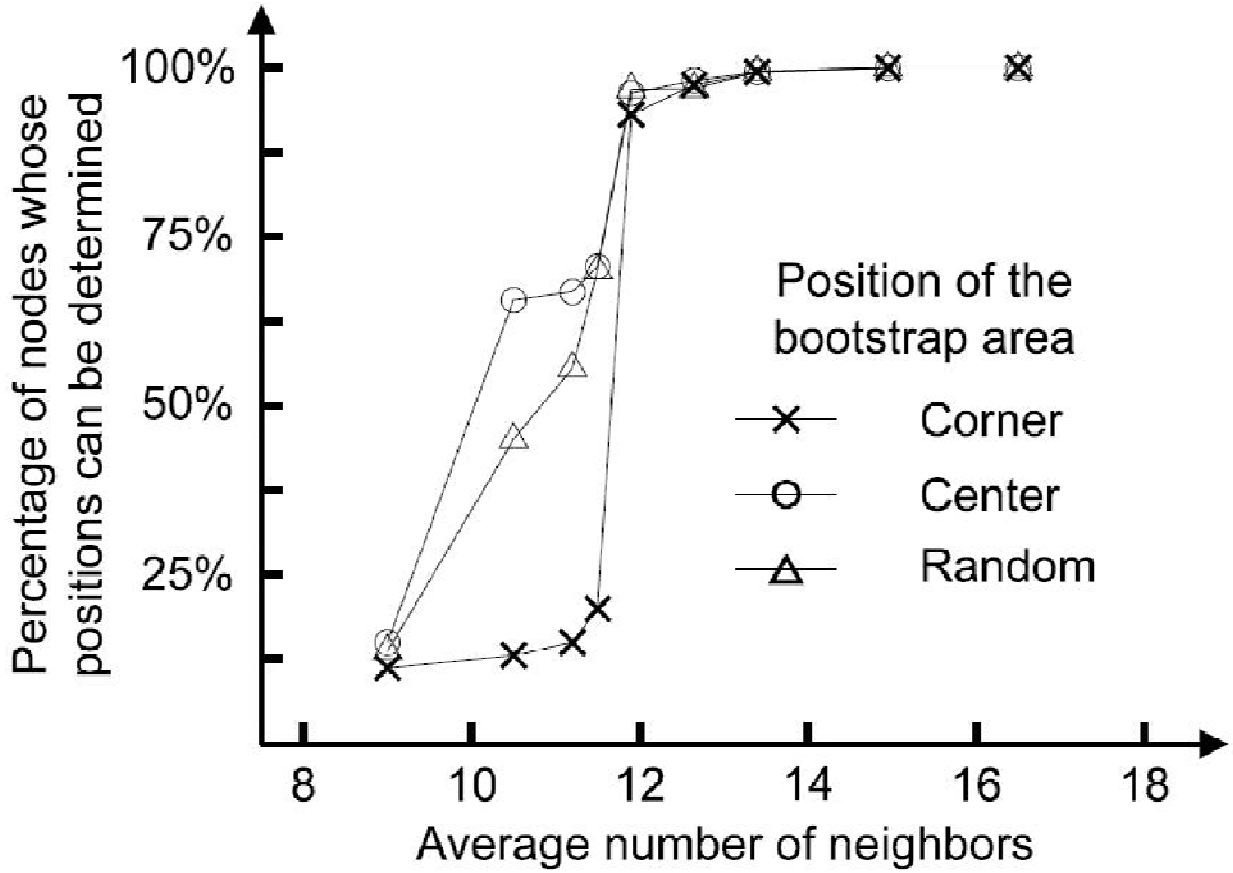
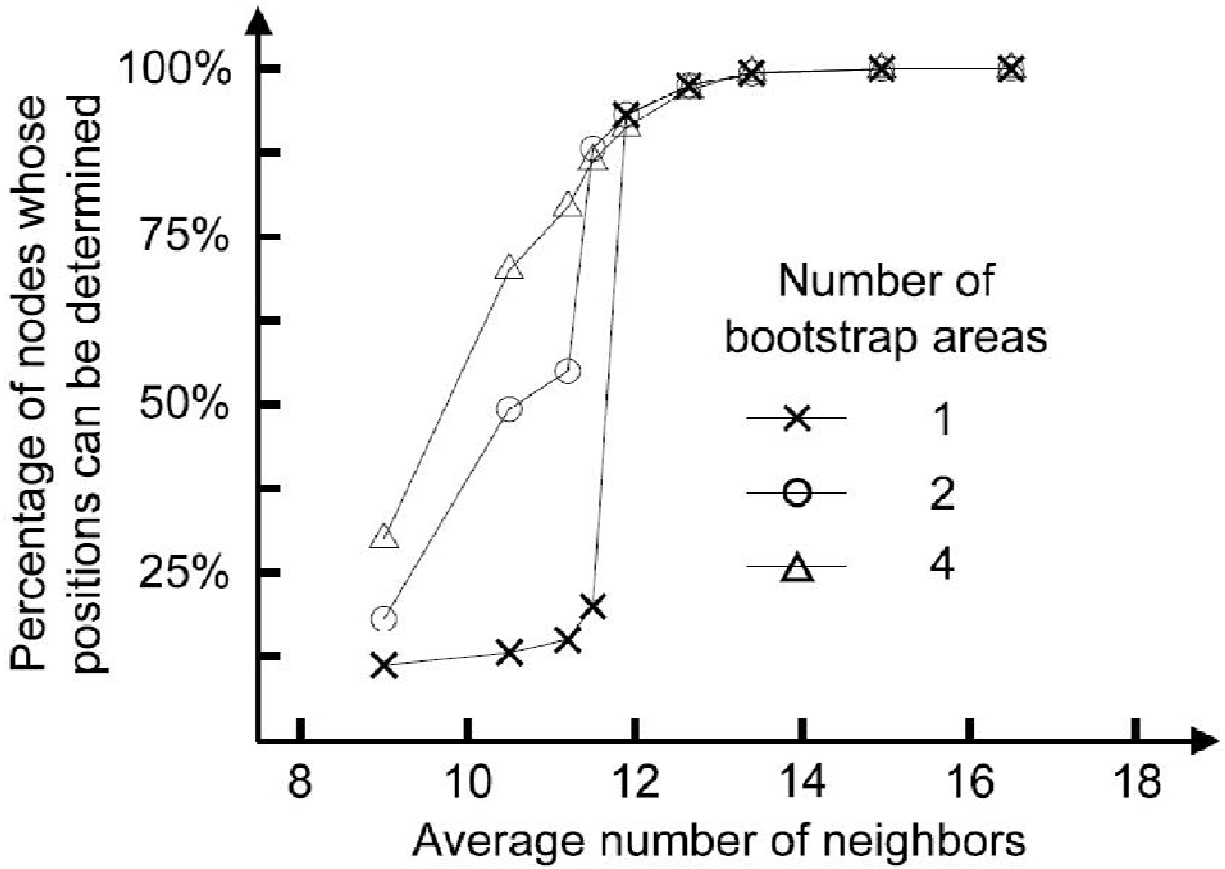
- Impacts of position of bootstrap area



- Impacts of number of bootstrap areas

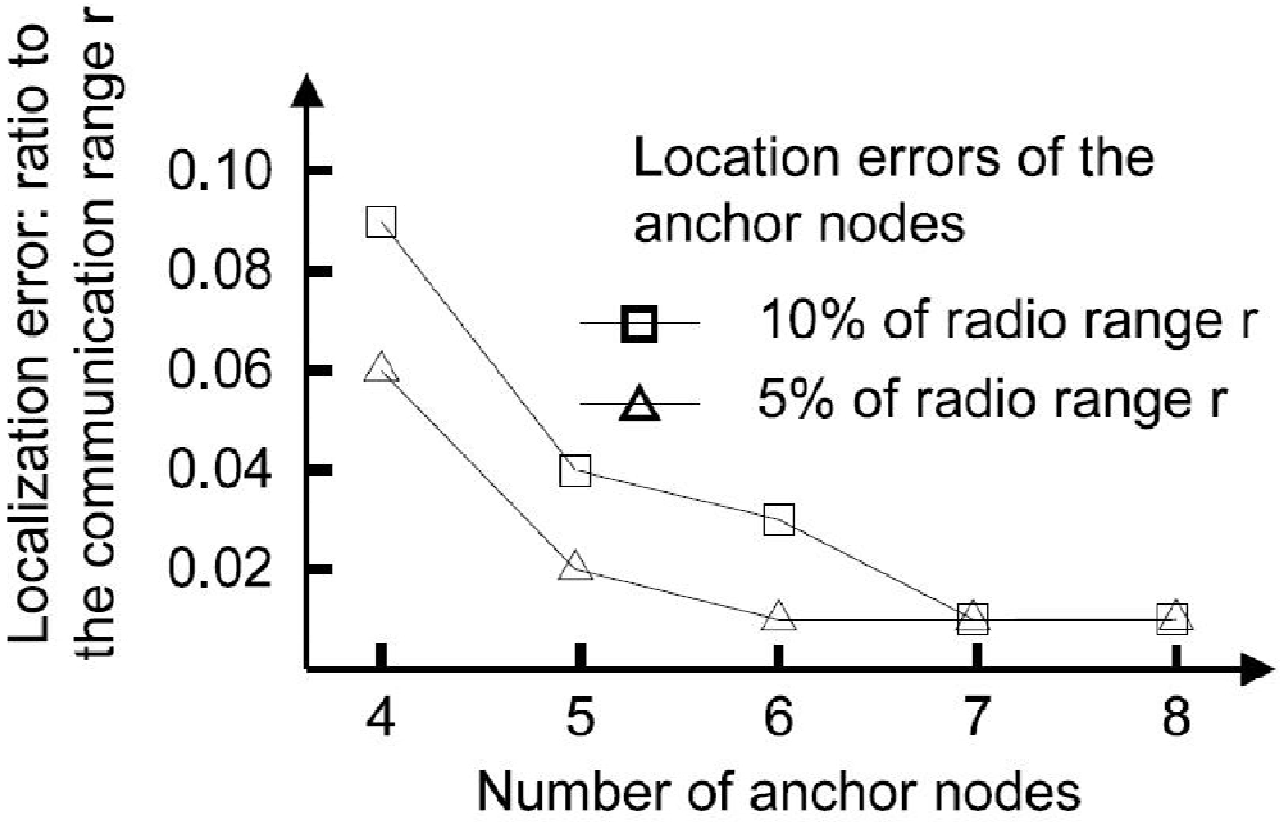


- Improving the localization accuracy
  - Identify the hyperbolas and intersections with errors and exclude their impacts
  - Use the intersection distribution function to quantify the density

$$DF(x,y) = \sum_{i=1}^{M} exp(-\frac{((x-x_i)^2 + (y-y_i)^2)}{\epsilon^2})$$

  - The uncertain area is a circle with the radius 0.7 to 1.5 times the positioning errors of the anchor nodes

- Using uncertain area to improve localization accuracy



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- Conclusions
  - Investigate the required node density for the proposed approach in self-organized networks
  - Study the localization inaccuracies caused by positioning errors of anchor nodes and design mechanisms to reduce their impacts
  - Help end users to determine whether or not this approach can be applied to their networks

- References

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