Opportunistic Routing in Mobile Ad-Hoc Networks Using Millimeter Wave and Random Beamforming

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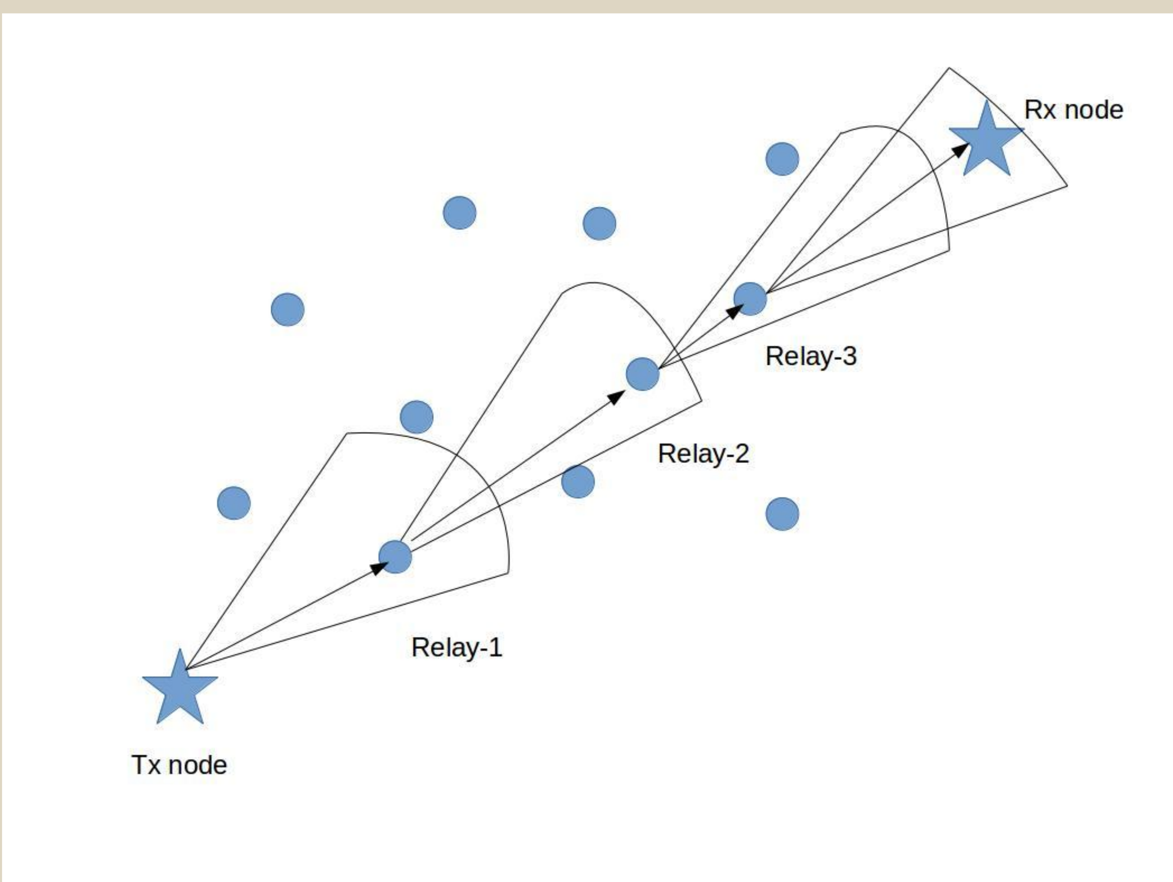
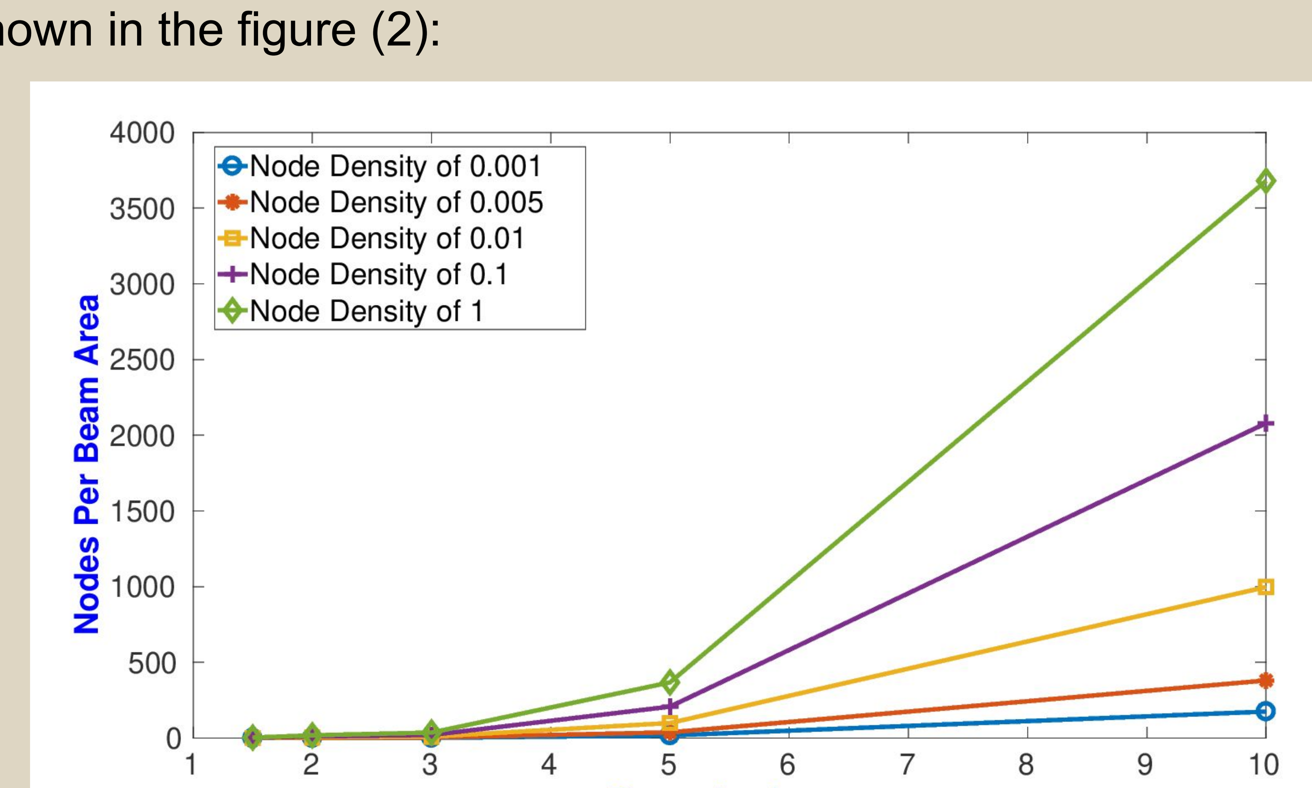
A new routing protocol for mobile ad-hoc networks that use mmWave has been suggested. By utilizing mmWave directional antennas, limited transmission range, and the random beamforming technique [1], this protocol can increase the network throughput, reduce the delay, and mitigate the effect of the interference of concurrent communicating nodes. See figure (1) for example ad-hoc network:



After the initial deployment of the nodes in and ad-hoc network, some nodes will have data to send. Nodes are assumed to have knowledge of its position and the position (coordinates) of the destination nodes. Also, each node should be able to perform random beamforming with different (adjustable) beamwidths (open angles).

Expected Number of nodes in each beam can be decided by many factors as shown in the figure (2):



Suggested opportunistic routing protocol can be expressed in terms of the sender and receiver nodes behavior. Original sender (or any intermediate relay node) will work according to the algorithm in figure (3).

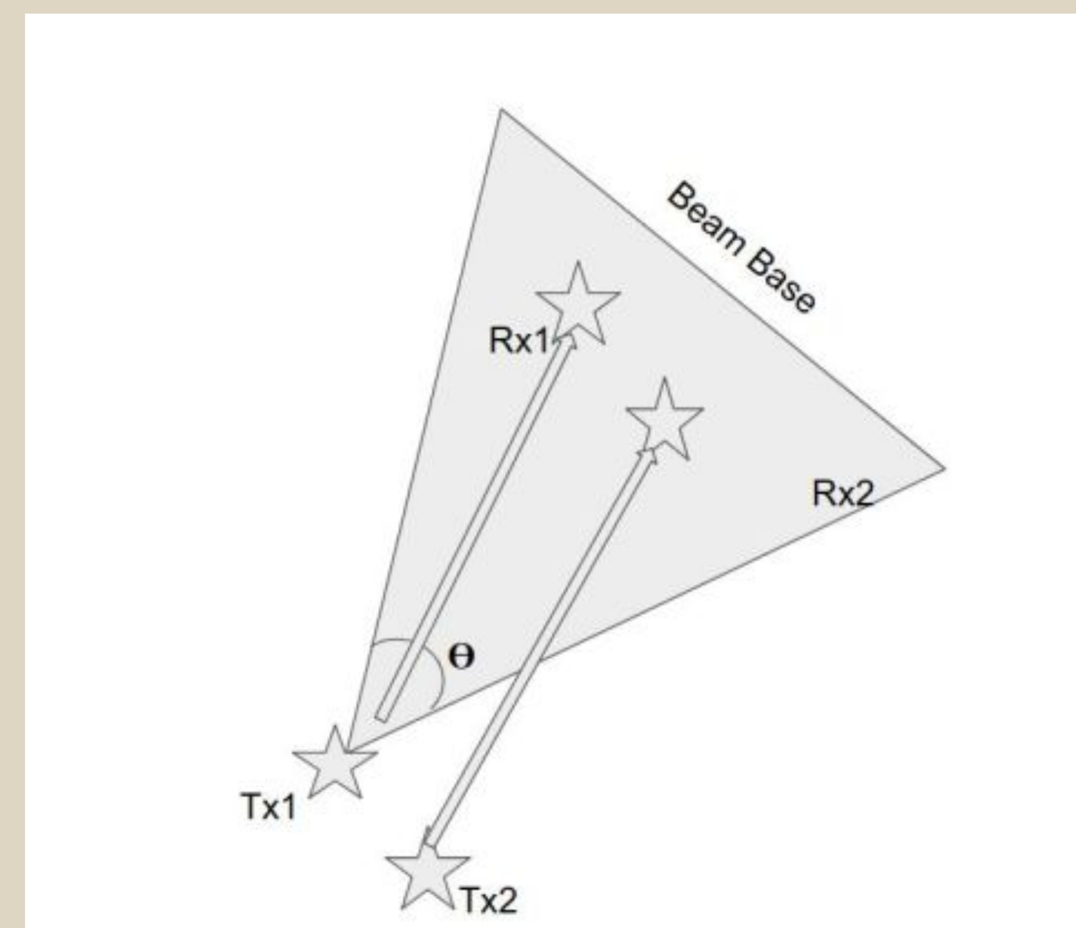
Algorithm Sender Algorithm

1: Begin:
2: A node has a data packet for transmission;
3: Perform random beamforming in the direction of the destination with small angle (ex. between 1-10 degrees).
4: **if** Receive feedback from nodes in that direction **then**
5: **if** More than one node with received SINR $\geq$ threshold **then**
6: Choose the one with the largest SINR and send data to it
7: Go to End
8: **else if** One node with received SINR $\geq$ threshold **then**
9: Send data to it
10: Go to End
11: **else**
12: Increase Beam Angle and to to line-3
13: **else**
14: Increase Beam Angle and go to line-3
15: End

Interference Analysis and Mitigation

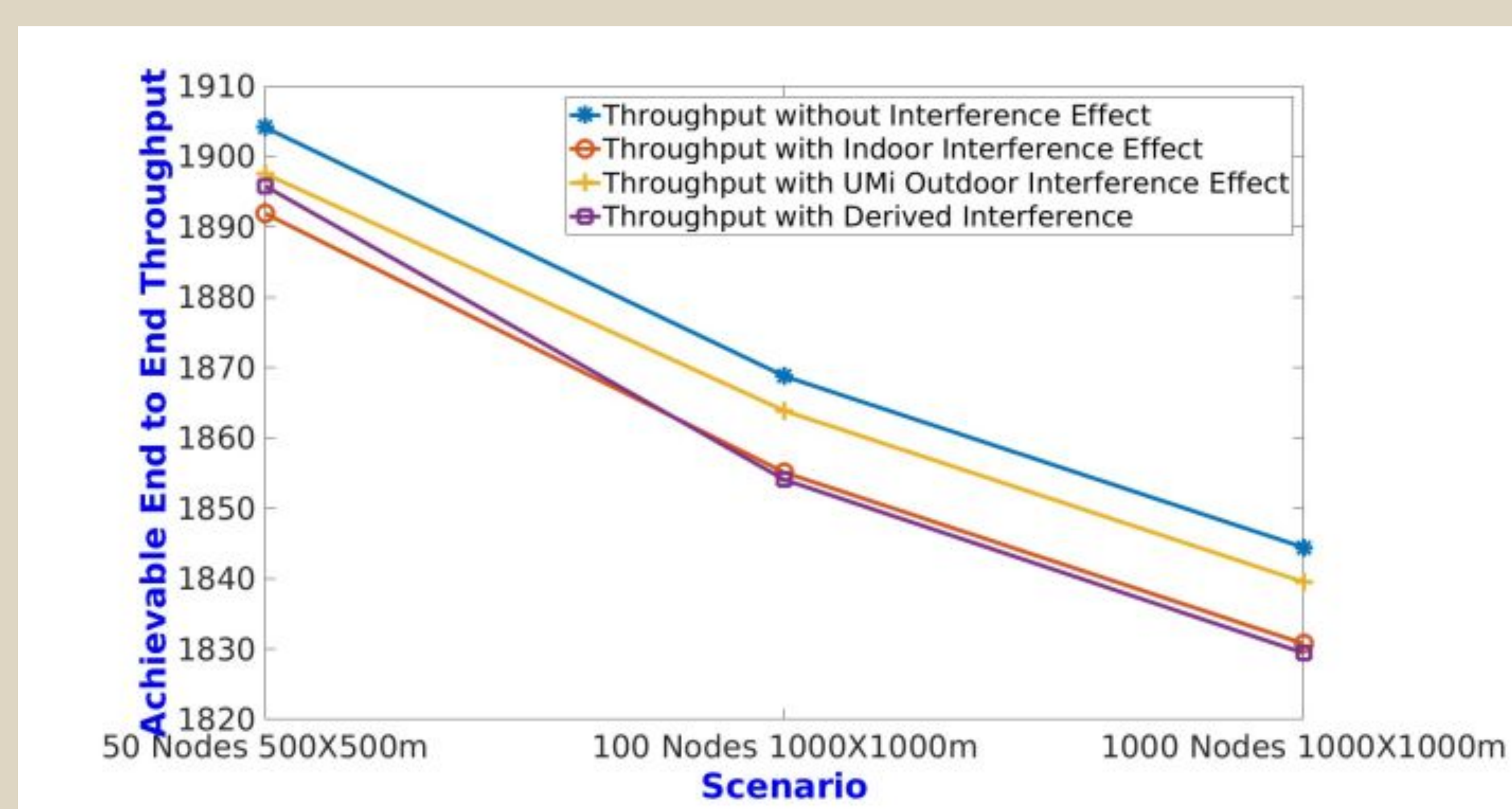
Our contention prevention scheme assures that, whenever a node is selected as a relay, other nodes that lost in the competition will backoff for a specific time (proportional to the propagation time of the packet and the expected hop distance), and that would prevent the collision among the transmitting nodes in the beam.

A simple illustration of possible interference scenarios is shown in figure (4) below:



Some Results

Different deployment scenarios were taken in considerations. Both per hop and end to end performance metrics were calculated to prove the better performance of our proposed protocol compared with the previously developed ones. An example of the expected end to end throughput in Mbps for different network sizes is shown in figure (5) below:



Conclusions and Future Work:

In this work, a new opportunistic routing protocol for mobile ad hoc networks that uses mmWave have been proposed. Mathematical performance analysis have been conducted and proved the feasibility of the proposed protocol compared with other opportunistic and geographic routing protocols both in terms of interference mitigation, achievable throughput, and the average delay reduction. Future work includes investing the user's mobility effect on the system performance and optimizing different system parameters for different scenarios.

References:

[1] Lee, Gilwon, Youngchul Sung, and Marios Kountouris. "On the performance of random beamforming in sparse millimeter wave channels." IEEE Journal of Selected Topics in Signal Processing 10.3 (2016): 560-575.

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