A Comparison of Flooding and Random Routing in Mobile Ad Hoc Networks

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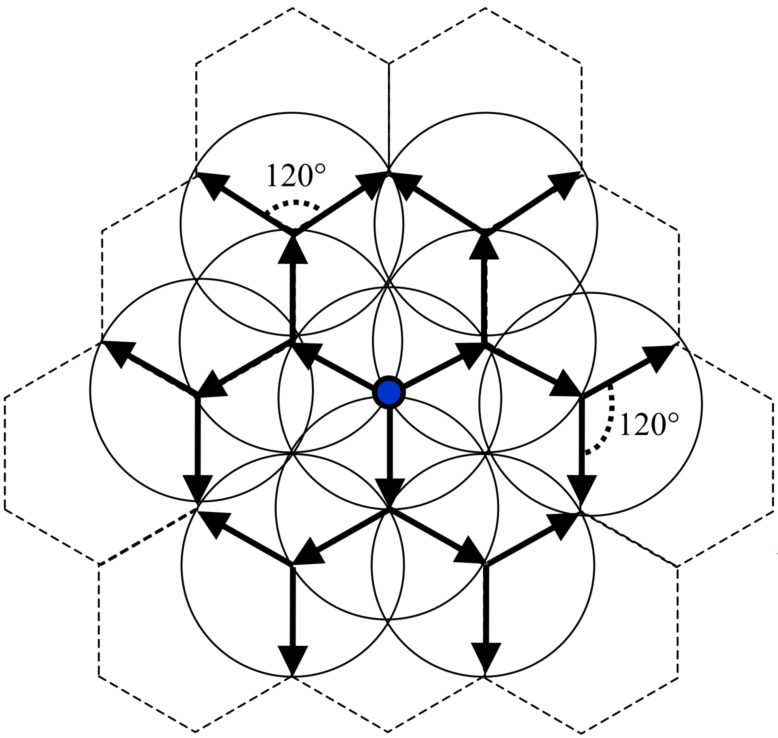
Introduction

- ✓ **Flooding**
  - To quickly broadcast a given message all over the network
  - To discover a destination in unknown networks
  - However, it propagates the number of unnecessary messages
- ✓ **Hexagon Flooding**
  - A kind of geographical flooding
  - Efficient flooding that significantly reduces the total number of redundant messages
  - Compared to the upper-bound efficiency of flooding
- ✓ **Random Routing**
  - To discover a destination in unknown networks
  - Uses fewer messages than flooding
  - Long average delay and large variance from source to destination

Hexagon Flooding



- Total number of messages needed = N, total number of vertexes

✓Selection Rules

- A source selects three edge nodes to make adjacent 120° angles
- Intermediate nodes select two edge nodes to make a 120° angle with the node from which it received the message
- If there is no edge node at the point calculated, select the nearest node to the point.

✓Stopping Rules

- Only selected nodes rebroadcast a given message once
- If a selected node cannot find any next forwarding node, it should not rebroadcast the messages
- If the node is not selected in the first received message, it should not rebroadcast the message

Analysis : Hexagon Flooding

✓Assumptions

- A mobile ad hoc network has high-density of nodes
- Every node has the same transmission radius
- Every node knows the geographical positions of itself and its neighbors within its transmission radius

✓Definitions

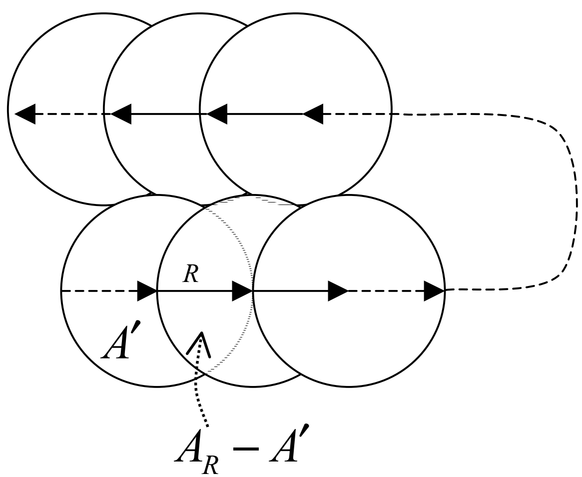
- Efficiency: $\eta = \frac{A_T}{nA_R}$ (1)
- Average number of messages received per node: $\frac{1}{\eta}$ (2)

✓Ideal Optimal Flooding

- An ideal routing that minimizes the total number of unnecessary messages in the given network.
- It may not be feasible but it can be used to estimate the upper-bound efficiency
- Any flooding scheme cannot exceed the upper-bound efficiency

Analysis : Ideal Optimal Flooding

- ✓ **A flooding scheme that minimizes total number of circles needed to cover the whole network**
  - It is achieved by minimizing overlapped area between circles
  - Minimal overlapping area : A_R-A′, because adjacent two nodes should be reachable each other
- ✓ **Upper-bound efficiency of flooding**

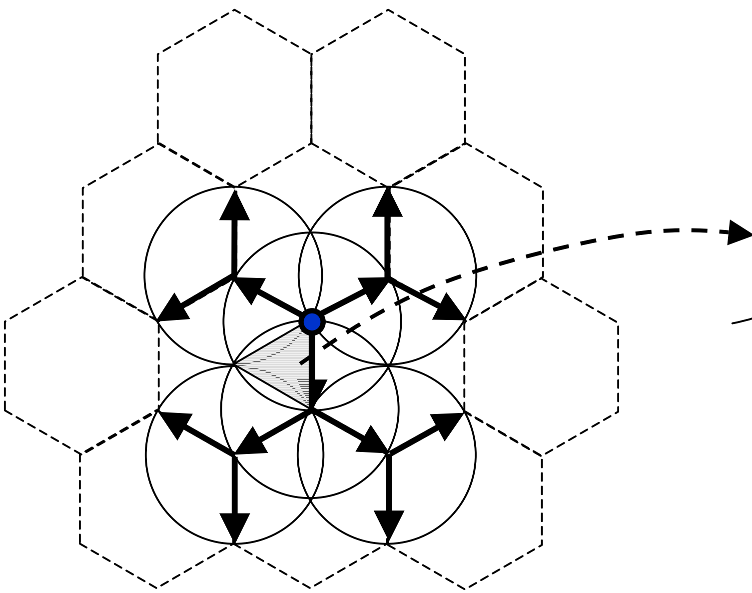


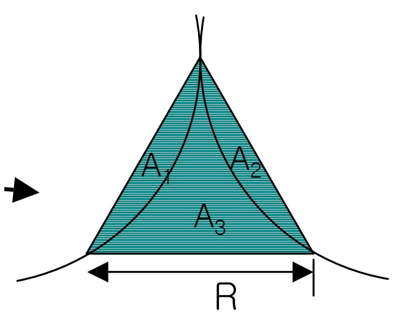
$$A' = \pi R^2 - 2\left(\frac{\pi R^2}{3} - \frac{\sqrt{3}R^2}{4}\right) = 1.913R^2 \qquad (3)$$

$$\eta = \frac{A_T}{nA_R} = \frac{n \times 1.913R^2}{n \times \pi R^2} = 0.6 \qquad (4)$$

Analysis : Hexagon Flooding

- ✓ **Analyzing the regular triangle is enough to estimate the efficiency η**
  - Re-broadcasting at every vertex node makes the same pattern
  - Assuming that the network is large enough to ignore the border effect
- ✓ **About 68% of the upper-bound efficiency**



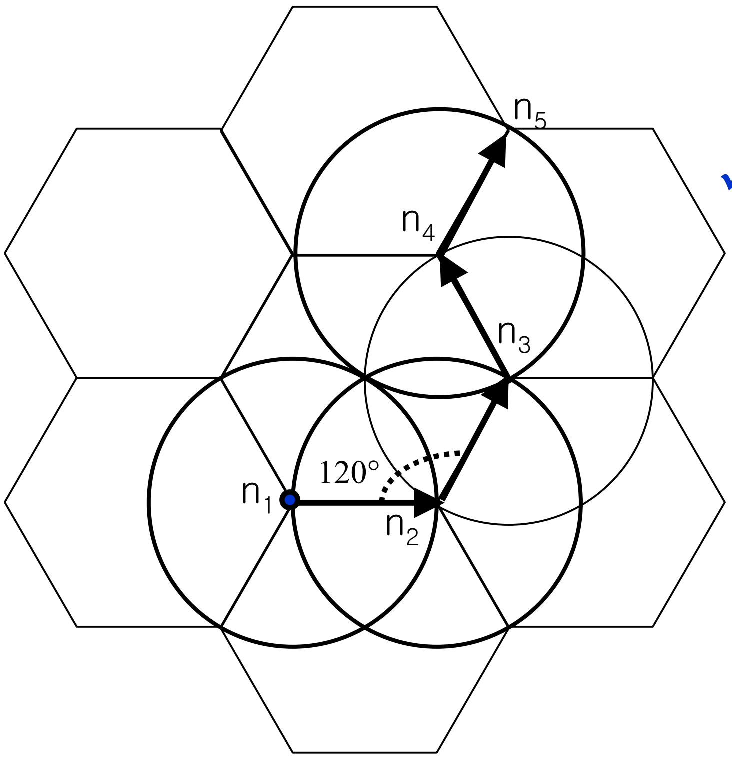


$$A_1 = A_2 = \frac{2\pi - 3\sqrt{3}}{12} R^2 = 0.09R^2 \quad (5)$$

$$A_3 = \left(\frac{3\sqrt{3}}{4} - \frac{\pi}{3}\right)R^2 \approx \frac{R^2}{4} \quad (6)$$

$$\eta = \frac{A_1 + A_2 + A_3}{3A_1 + 3A_2 + 2A_3} = \frac{0.43R^2}{1.04R^2} = 0.41 \quad (7)$$

Random Routing



✓**Assumptions**

- A node has first-order neighbor knowledge, k=1
- High density networks

✓**Random routing on the arms of the hexagon**

- A source selects one of the edge nodes and forwards a given message
- If the next node has the destination information, the message is forwarded to the destination.
- If not, the node randomly selects one out of two edge nodes for the next forwarding node and forwards the packet

Analysis : Random Routing

- **How many messages are needed until the message arrives at the destination?**
  - How many hops on average are needed from source to destination?
  - Let p be the probability that the message is forwarded to its destination zone on the next hop

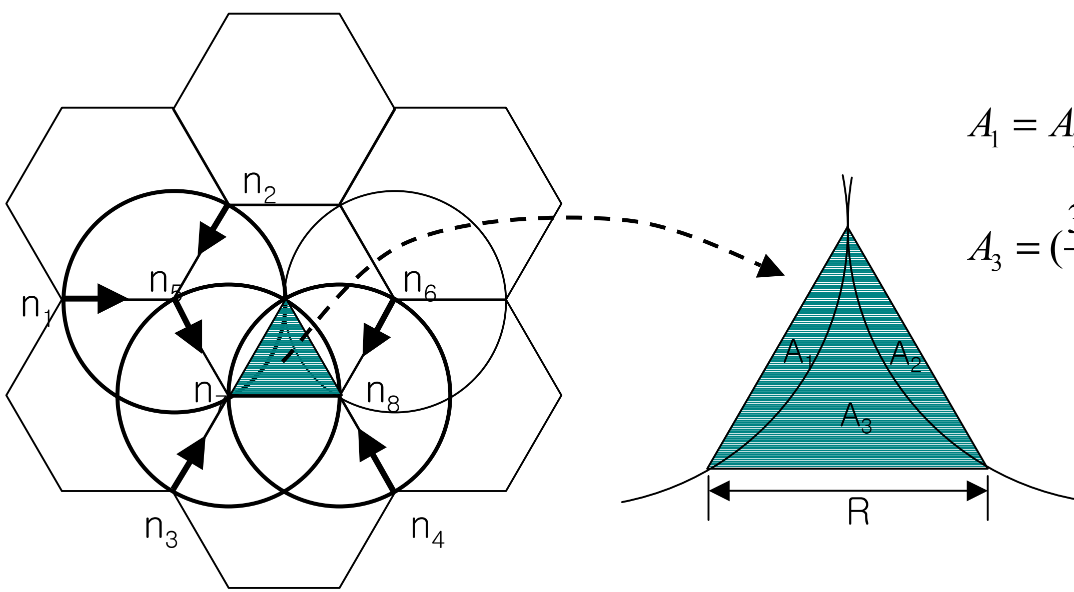
$$P(n) = p(1-p)^{n-1} \quad (8),\qquad m = \frac{1}{p} \quad (9),\qquad \sigma^2 = \frac{1-p}{p^2} \quad (10)$$

- **Destination zone**
  - A set of nodes that have the destination information
  - Once a message arrives at the destination zone, it is definitely forwarded to its destination on the next hop
- **The probability p depends on**
  - The location of source
  - The location of destination

Analysis : Random Routing

✓**Analyzing the triangle to estimate the probability p**

- Broadcasting at the vertex nodes makes the same pattern throughout the network, the regular triangle.
- The destination may appear anywhere in the network with the same probability
- Every possibilities on the relative locations of source and destination can be explained with the regular triangle
- In large networks, we ignore the border situation.



$$A_1 = A_2 = \frac{2\pi - 3\sqrt{3}}{12} R^2 = 0.09 R^2 \quad (11)$$

$$A_3 = (\frac{3\sqrt{3}}{4} - \frac{\pi}{3}) R^2 \approx \frac{R^2}{4} \quad (12)$$

Analysis : Random Routing

- ✓The conditional probability that a message arrives at the destination zone on the next hop, given that the destination is located in A_1 (or A_2)

$$P(E \mid A_1) = P(E \mid A_2) \approx \frac{4.17}{N} \qquad (13)$$

- ✓The conditional probability that a message arrives at the destination zone on the next hop, given that the destination is located in A_3

$$P(E \mid A_3) \approx \frac{3.33}{N} \qquad (14)$$

- ✓The probability that a message arrives at the destination zone on the next hop

$$p = P(E \mid A_1)P(A_1) + P(E \mid A_2)P(A_2) + P(E \mid A_3)P(A_3) \qquad (15)$$

$$\approx \frac{3.68}{N}$$

Conclusion

	Hexagon Flooding	Random Routing
The average # of messages needed from source to destination	$m = N$	$m = \frac{N}{3.68}$
Variance	$\sigma^2 = 0$	$\sigma^2 = \left(\frac{N}{3.68}\right)^2$
Delay	A few number times t Where t is an average time per hop	$T = \frac{N}{3.68} \times t$
	Short delay and no variance, but more messages	**Fewer messages, but large variance and long delay**

Conclusion

- ✓ **Hexagon Flooding and Random Routing on the arms of the hexagon works well in high-density mobile ad hoc networks**

- ✓ **The efficiency of hexagon flooding reaches 68% of the upper-bound efficiency**
- ✓ **The hexagon flooding is scalable with the number of nodes in the specified region**

- ✓ **Random Routing uses on average one-third of the total number of messages that are required in flooding to locate a destination**
- ✓ **With the random routing, increasing order of neighbor knowledge can further reduce the number of messages**
- ✓ **Our study shows that about 97% of the time, random routing uses fewer copies of the messages than flooding**

Future Work

✓**Completion of Hexagon Flooding**

- Apply to the low-density mobile ad hoc network
- Apply to the obstacles networks
- Simulation

✓**Potential Routing**