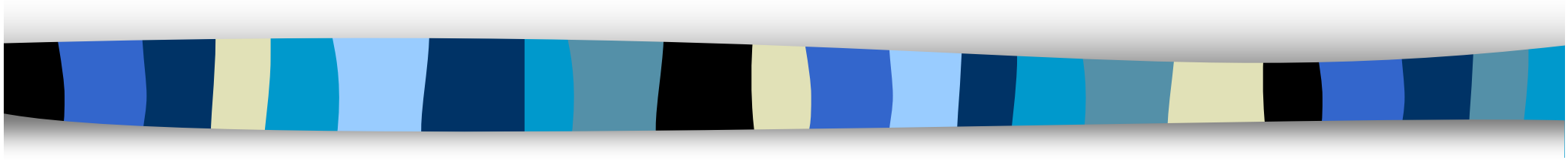
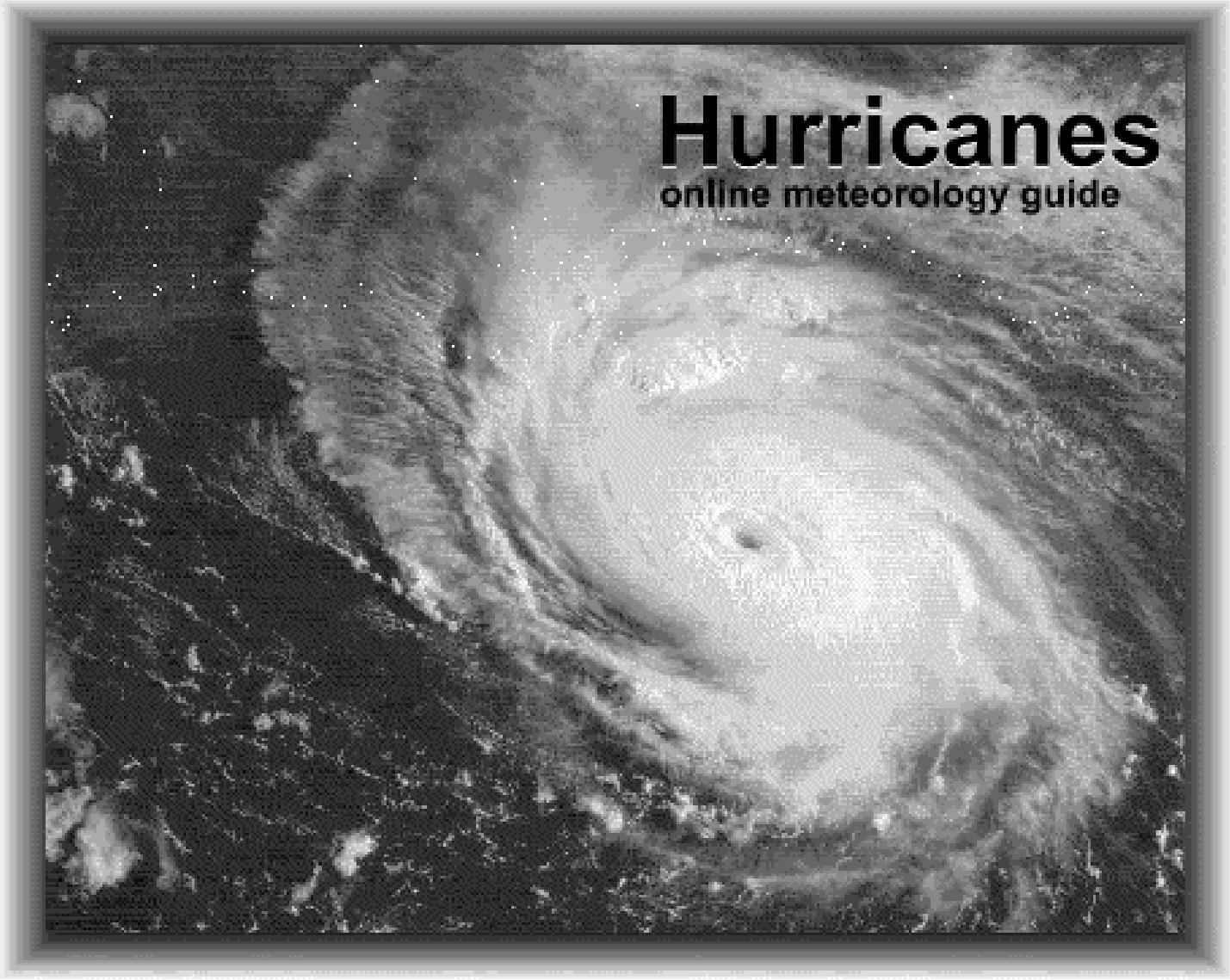
國立臺北大學 資訊工程學系
NTPU, Department of Computer Science and Information Engineering

Chapter 10: The Broadcast Storm Problem in MANETs



Prof. **Yuh-Shyan Chen**
Department of Computer Science and Information Engineering
National Taipei University
Dec. 2007

Storms of Nature



T-Storm in St. Louis

“Touchdown” of a Tornado

Can Human Create Storms?

The Storms in the Internet

Subject: 我有六千一百萬筆最新Email名單，我只賣 NT$3000元!
Date: Sun, 11 Jul 1999 18:47:21 +0800 (CST)
From: ****@***.university.edu
To: <yctseng@csie.ncu.edu.tw>

你想要賺錢嗎？
你可以在花費極少的情形下，接觸到全世界六千萬一百萬人！
是的！沒錯！ 我有六千一百萬筆最新Email名單，我只賣 NT$3000元！！！
這些都是最新的地址，基本上可說包含了網際網路上所有的人，
而且這些地址沒有一個是重複的！！！
並且都已經過排序整理過了，可以立即上手使用！！！
這可能是當今市場上所能找到最物超所值的交易了！！！
想想看，賣一個五十塊錢的商品，如果回收率只有千分之一，
就有三百零五萬元進到你的口袋了!!!

(a 3-page long email ...)

Call for Papers

Dear Friends,

Sorry if you receive the duplicate messages.
But please distribute the following message to your friends.

*Prof. ***, University of %%%*

****

Call for Papers
International Conference on ????
IC???'99
to be held in ???, ???, September ???, 1999
http://www.???/conf/ic???99

THEME:
Research on mobile computing is gaining more and more attention ...
...

The Storms in the Internet

Subject: Hold on! Don't throw out this message yet!
Date: Wed, 30 Jun 1999 07:35:40 +0800 (CST)
From: Rory.Bellows@chu.edu.tw
To: you@chu.edu.tw

Dear Sir or Madam,

Allright, I'm not going to give you any bull. This is "junk" mail, but if you will please just give me 60 seconds of your time and read the next paragraph, maybe I can change your mind. Just 60 seconds. What have you got to lose?

Below is a message I got last month. I said "junk," and was dragging the icon to my trash can when I figured "what the hell," and began reading it. I ALWAYS throw stuff like this out. But I read. And now I'm rolling in $$$. This works and I'm not kidding. At first it sounds like your typical "pyramid scheme" scam, but it's not - the difference is that you're actually selling a product! I won't go into the details right now, if you're interested you can keep reading the rest of the message. I just want to say a couple things. First, don't take my word for it that this works. Use your own head. Just read this message and think about the process logically. You'll see that it won't fail! Second, just make sure you follow the instructions TO THE LETTER. I can't stress that enough. ...

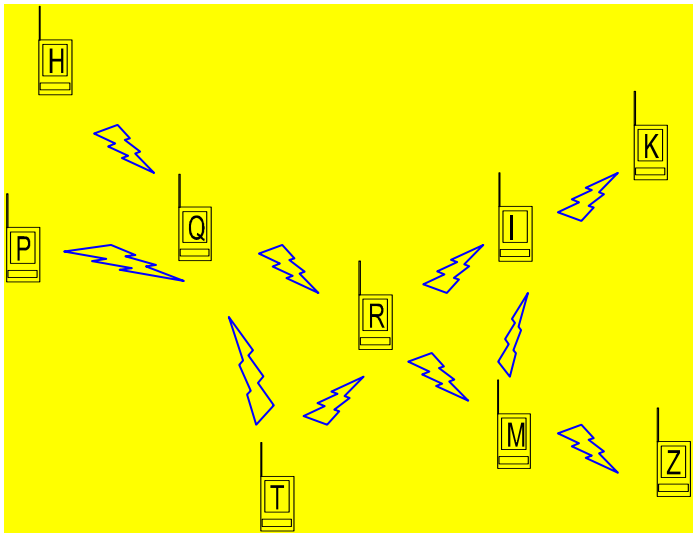
JUST DO IT!! Yeah, it's a long message to read, but it's worth it!

Thanks,
Rory

... (a 5-page-long email)

Broadcast Problem

- Broadcast: the sending of a message to other hosts
  - Ex: Route search in a MANET
  - Ex: DSR, AODV, ZRP protocols.



- Assumptions:
  - The broadcast is spontaneous.
    - no synchronization
    - no prior global topology knowledge
  - The broadcast is unreliable.
    - no acknowledgement of any kind
      - ✓ not to cause more contention
      - ✓ 100% reliability is unnecessary for some application
  - No RTS/CTS dialogue.

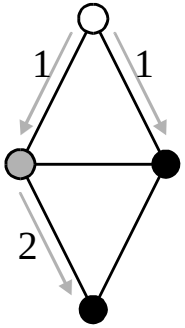
Broadcast by Flooding

- A straight-forward approach
  - A host **rebroadcasts** the message on receiving a broadcast message for the first time.

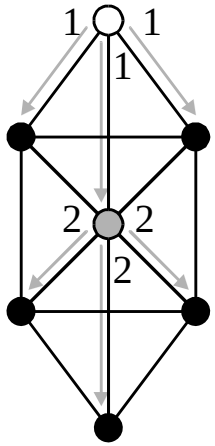
- ***Broadcast storm problem***:
  - redundant rebroadcasts
  - contention problem
  - collision problem

Serious Redundancy

- Optimal broadcasting vs. Flooding
  - (a) optimal = 2 steps
  - (b) optimal = 2 steps

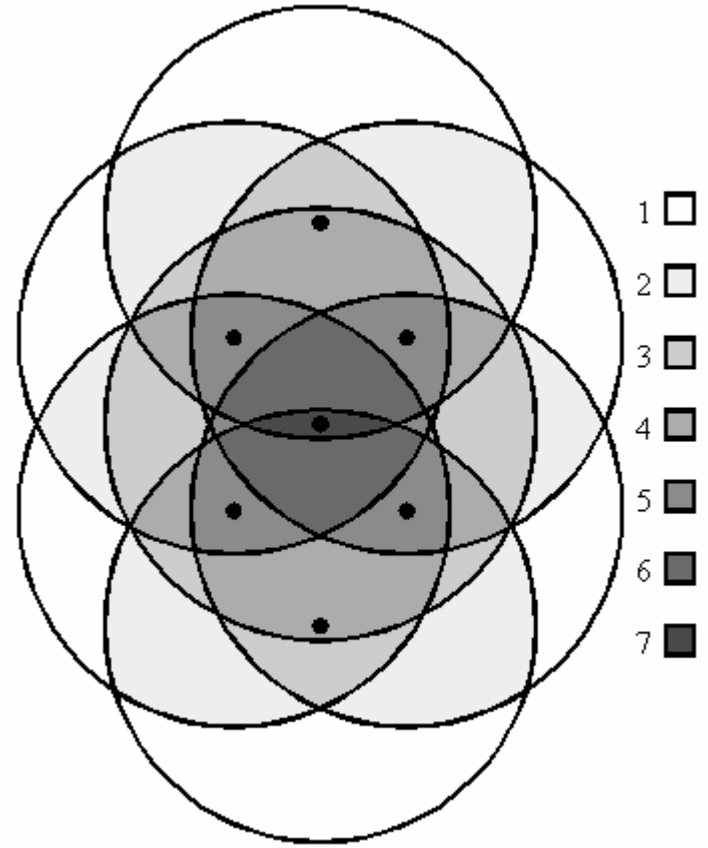


(a)



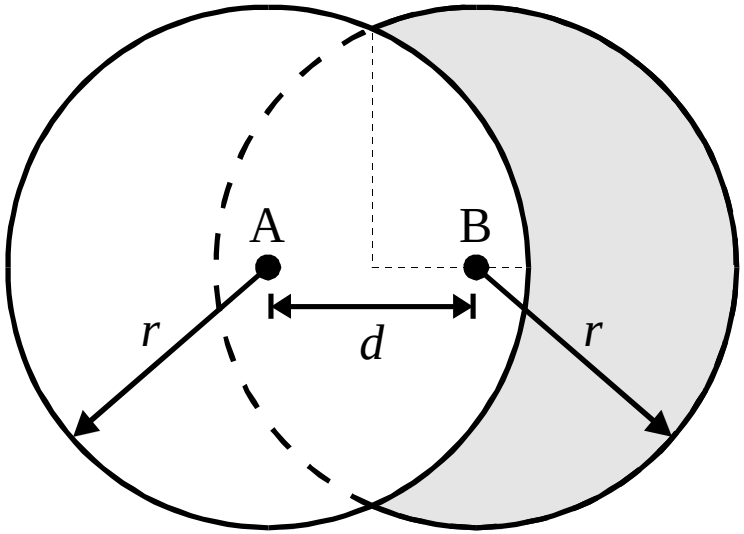
(b)

- Severity of Redundant Coverage.

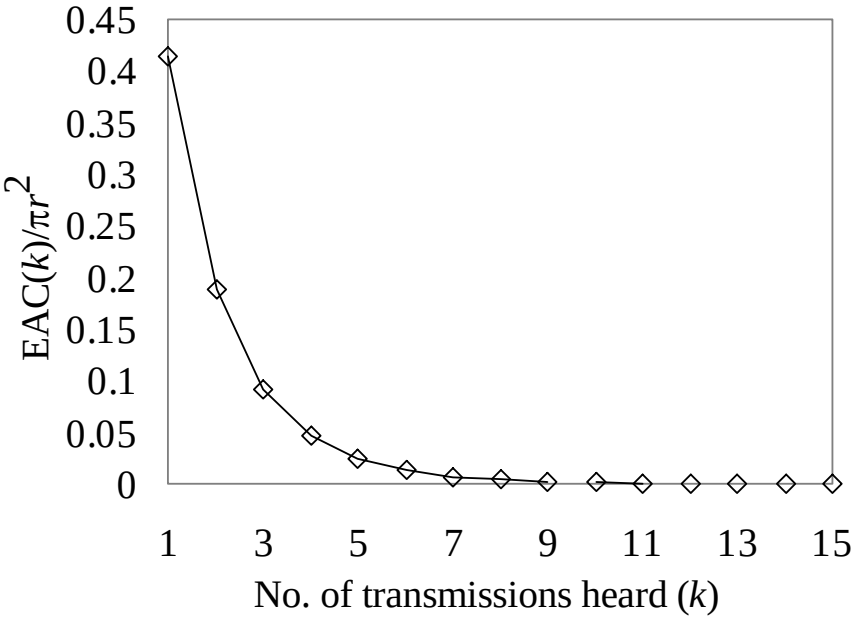


Analysis on Redundancy

- ***Additional Coverage*** provided by a rebroadcast.
  - The max. additional coverage is 61%.
  - The coverage is 41% in average.

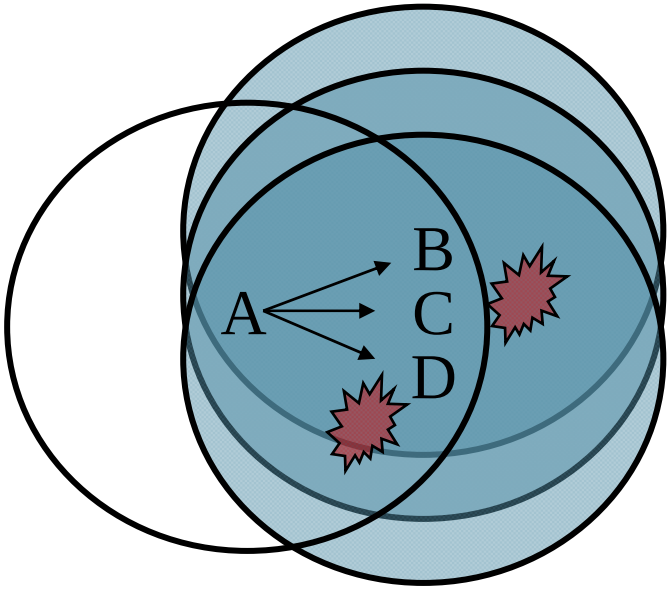


- The expected additional coverage $EAC(k)/\pi r^2$ after a host heard a broadcast message k times.

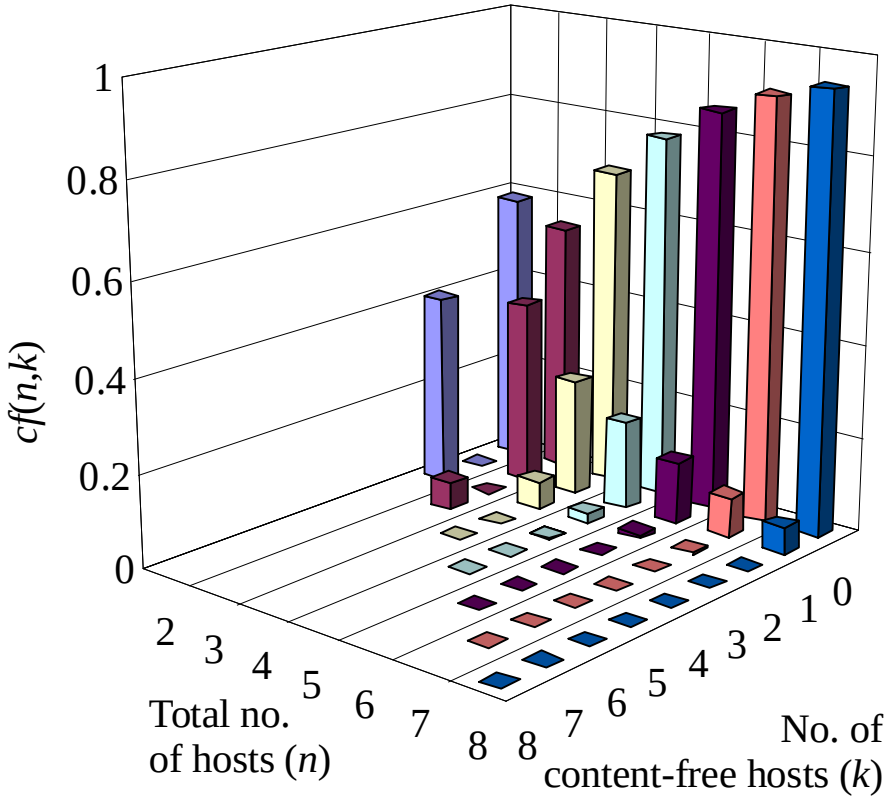


Analysis on Contention

- When a host broadcasts, its neighbors are likely to contend with each other for the medium.
  - A ==> B, C, D
  - B, C, D could seriously contend with each other.

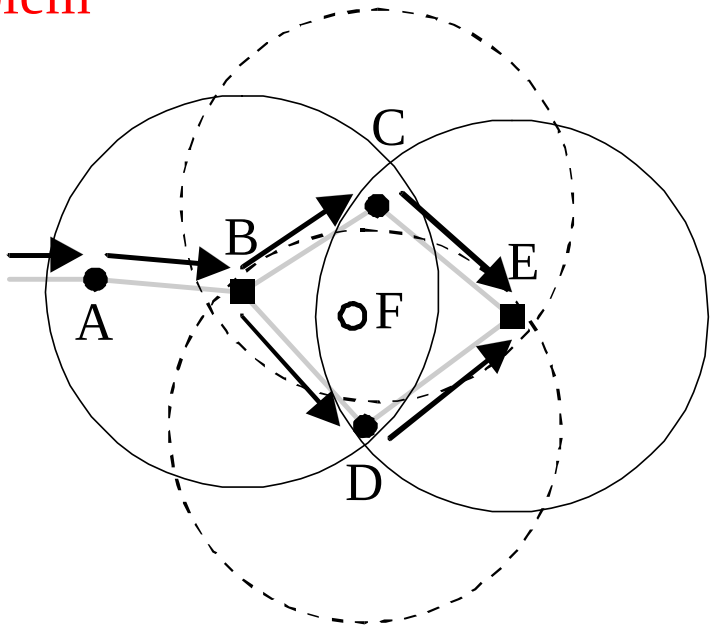


- *cf(n, k):* The probabilities of having *k* contention-free hosts among *n* receiving hosts.



Analysis on Collision

- Higher Possibility of Collision:
  - Rebroadcasts are likely to start at the same time.
    - Backoff window runs out if medium is quiet for a while.
  - lack of RTS/CTS dialogues
  - lack of collision detection (CD) if collision occurs
  - hidden terminal problem



Broadcast Storm Problem Summary

- Redundancy
- Contention
- Collision
- How to derive an efficient scheme for broadcasting in a MANET?

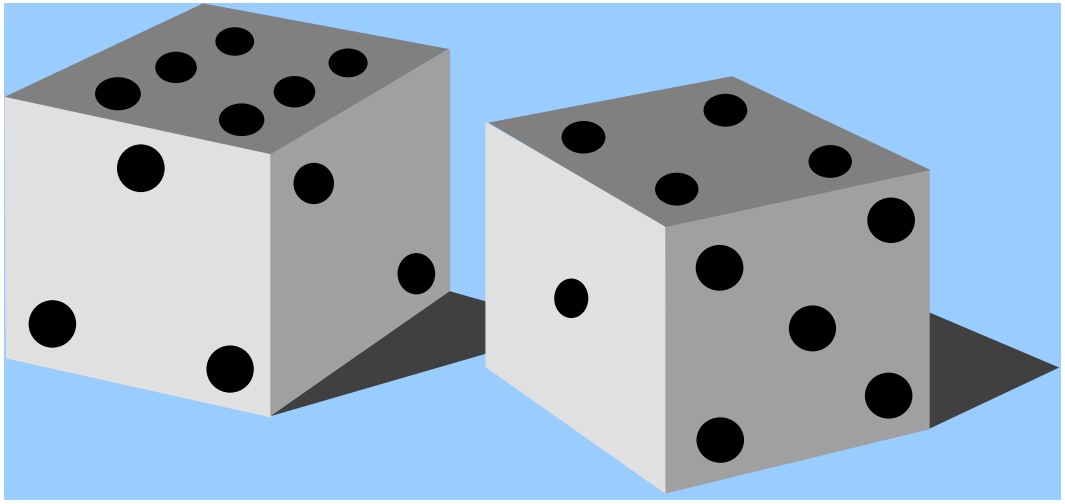
Possible Broadcast Solutions

- Probabilistic Scheme
- Counter-Based Scheme
- Distance-Based Scheme
- Location-Based Scheme
- Cluster-Based Scheme

Probabilistic Scheme

- Rebroadcast by "Tossing a Die"

- A host always rebroadcasts with a certain probability P.
  - When P = 1, this is flooding.
  - A smaller P will reduce the storm effect.



Simulation Parameters

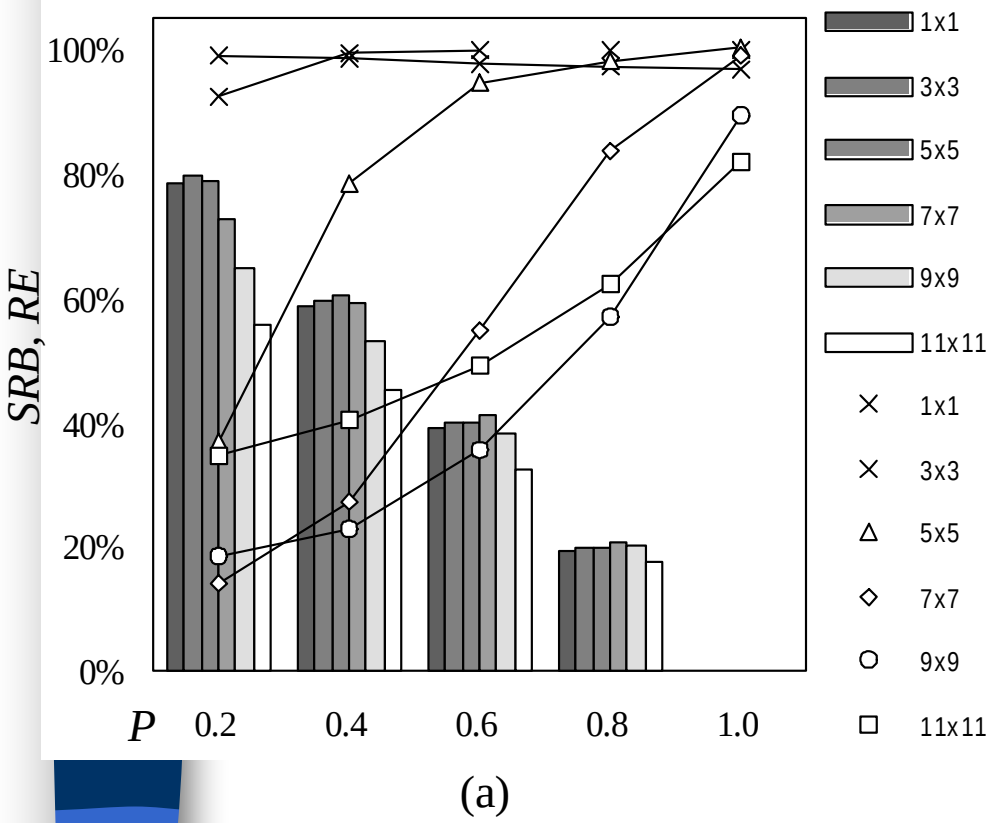
- no of hosts = 100
- transmission radius = 500 meters
- packet size = 280 bytes
- transmission rate = 1 M bits/sec
- broadcast arrival rate: 1 per sec. to the whole map
- map: (1 unit = 500 meters)
  - 1x1, 3x3, 5x5, 7x7, 10x10
- roaming pattern: random walk
  - speed: 0~10 km/hr in a 1x1 map, 0~30 km/hr in a 3x3 map, etc.
- IEEE 802.11 without PCF (point coordination function)

Performance of Probabilistic Scheme

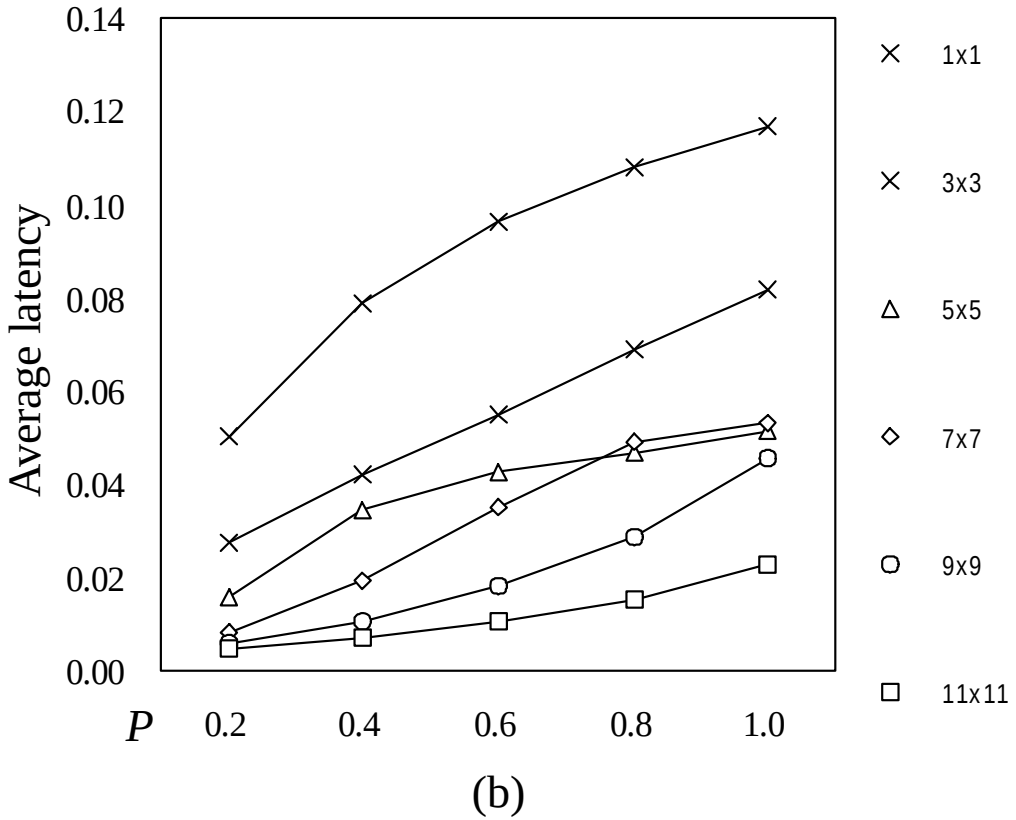
RE = REachability (in lines)

SRB = Saved ReBroadcast (in bars)

Latency



(a)



(b)

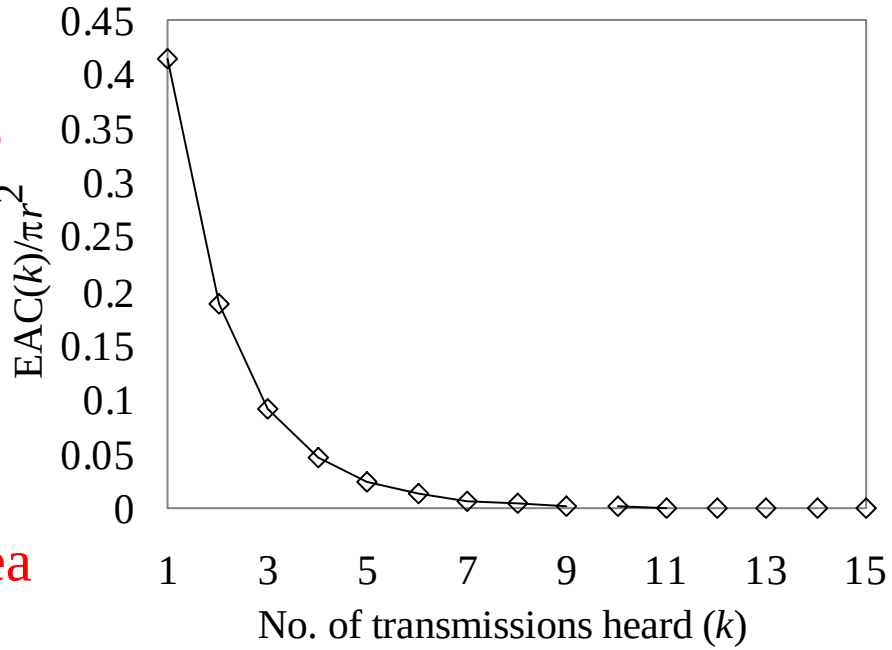
Observation

- Reachability:
  - In smaller maps, a low P is sufficient to achieve high reachability.
  - A larger P is needed in a larger map.
- Saved Rebroadcast:
  - linear with respect to P
- Latency:
  - Interestingly, in smaller areas, broadcast tends to complete in a slower speed.

Counter-Based Scheme

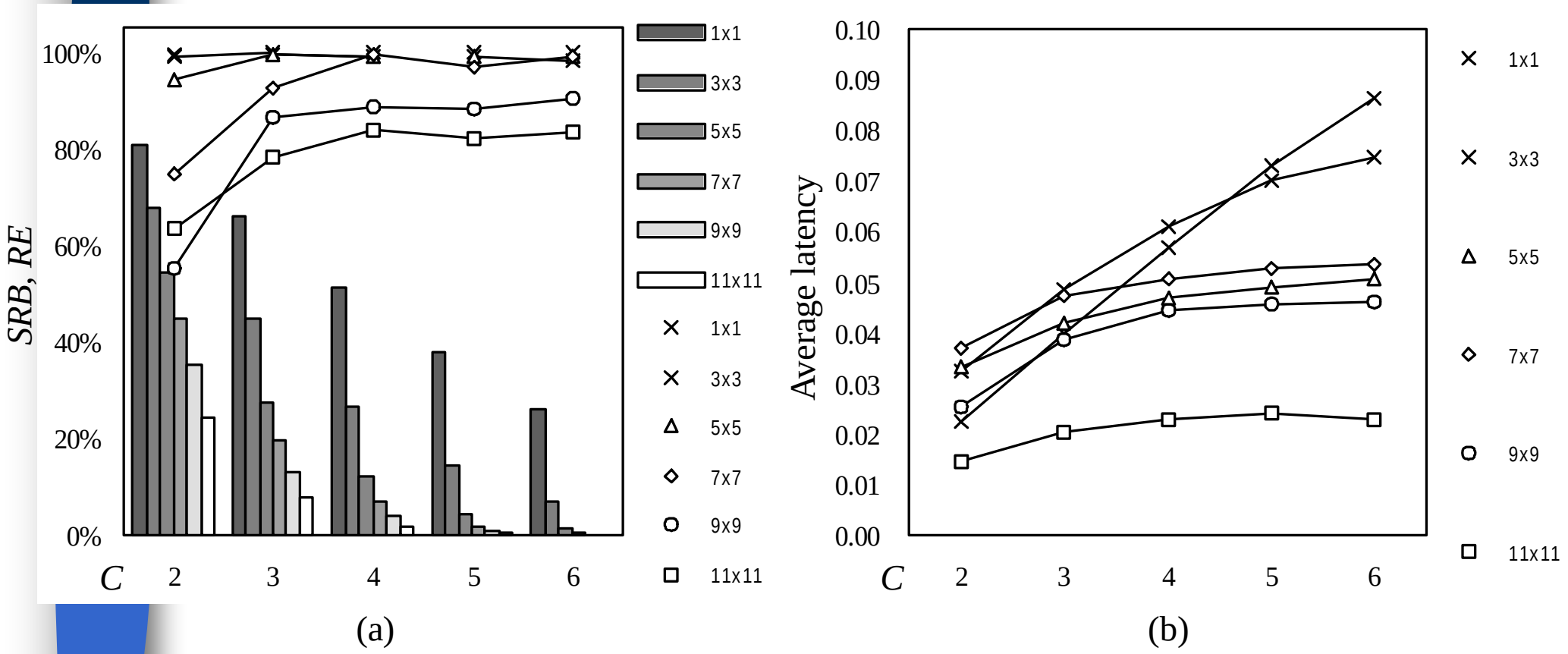
- If a host has received a broadcast packet > C times,
  - then do not rebroadcast.

- Examples: Addition Coverage
  - 1 time => 41%
  - 2 times => 19%
  - 3 times => 9%
  - 4 times => 5%
  - > 4 times, very little extra area



Performance of Counter-Based Scheme

- We vary C = 2, 3, ..., 6 to observe the performance.
  - A larger C means more rebroadcast.

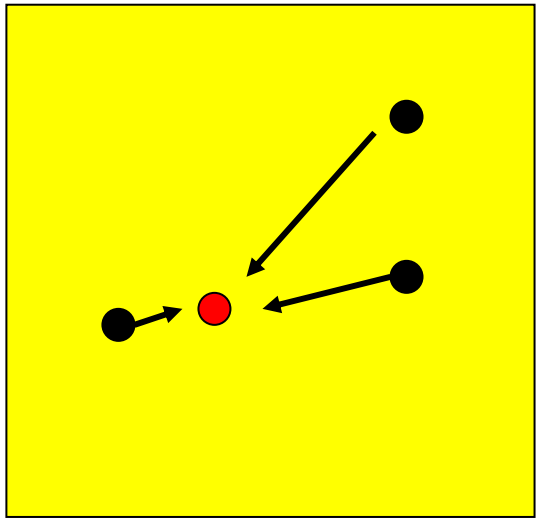


Observation

- Reachability:
  - C >= 3 can offer a reachability close to flooding.
- Saved Rebroadcast:
  - In denser area, there is more saving. In sparser area, there is less saving.
- Latency:
  - Higher latency is smaller area.

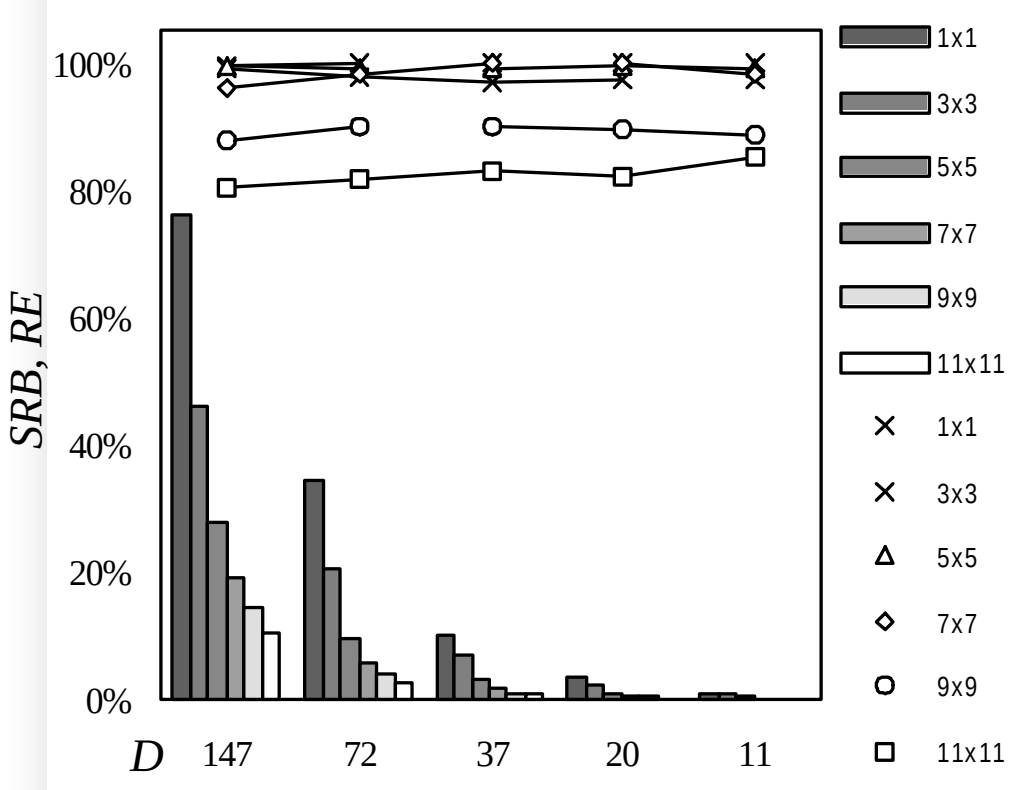
Distance-Based Scheme

- Calculate the distance to the sending host.
- d_{min} = Min{the distance to each sending host}
- If d_{min} < D (a threshold), then do not rebroadcast.
- How to find distance:
  - signal strength
  - GPS devices

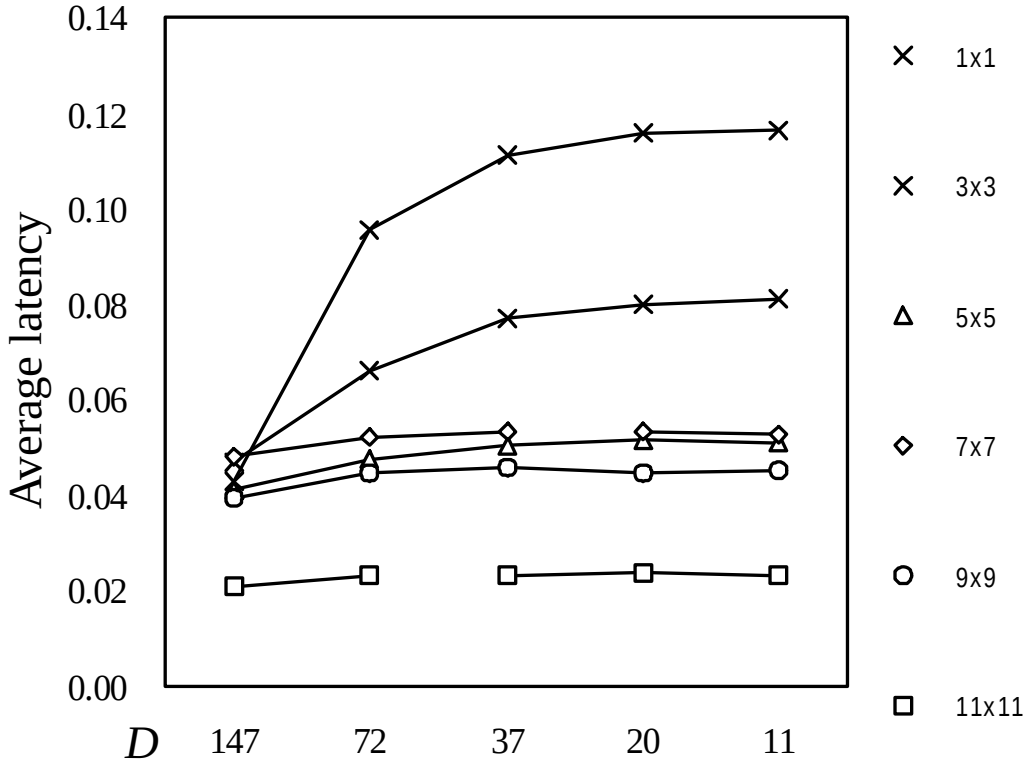


Performance of the Distance-Based Scheme

- We vary D = 147, 72, 37, 20, 11 to observe the effect.
  - Smaller D means more rebroadcasting.



(a)



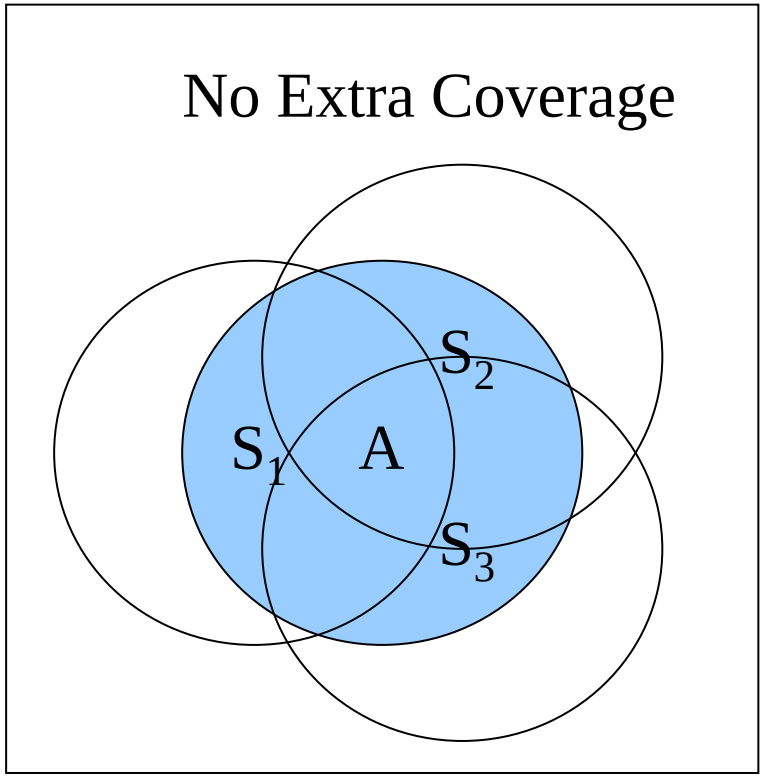
(b)

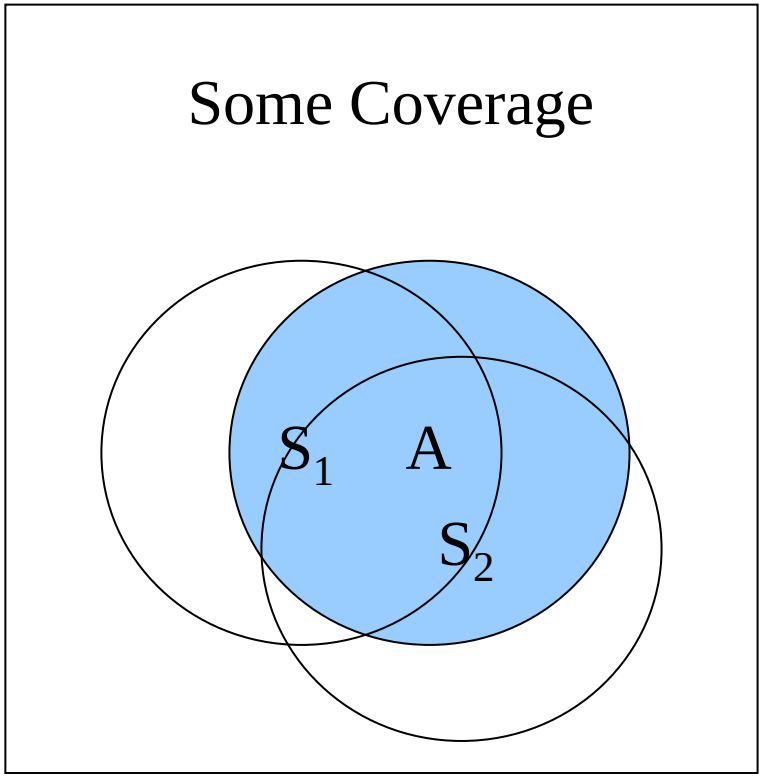
Observation

- Why choosing D=147?
  - addition coverage = 0.187, equal to that of C=2
- Reachability:
  - All look good, close to flooding.
- Saved Rebradcast:
  - not much
- Latency:
  - smaller area has higher latency

Location-Based Scheme

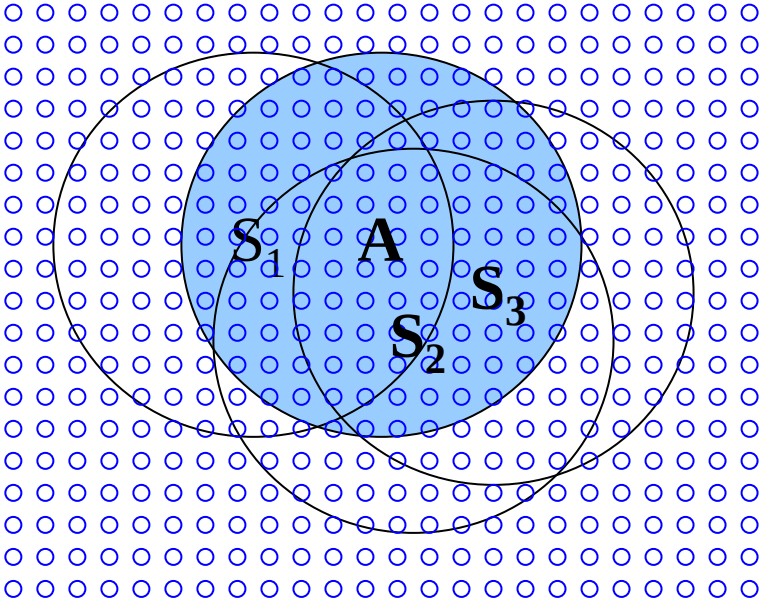
- From GPS to obtain the sender's location.
- Let (x_1, y_1), (x_2, y_2), (x_3, y_3), ..., (x_k, y_k) be locations of senders.
  - We can accurately calculate the additional coverage of this rebroadcast.





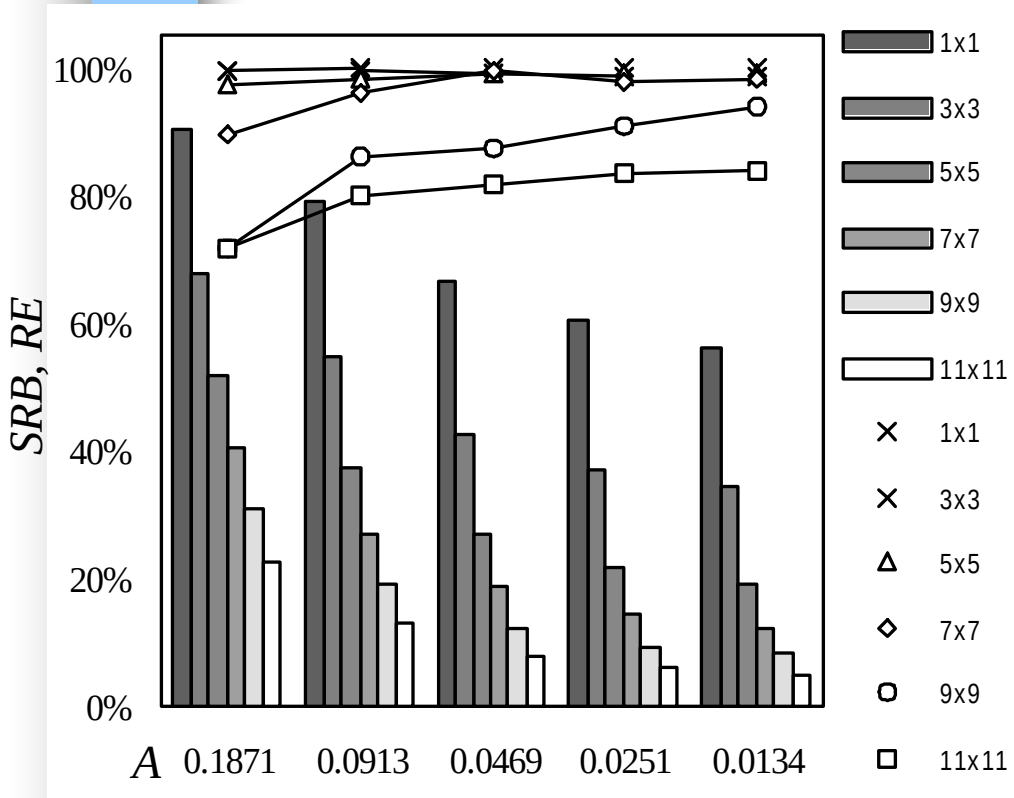
Difficulty

- Involve complicated math to calculate the extra coverage.
  - A lot of calculus!
- Approximation:
  - grid simulation

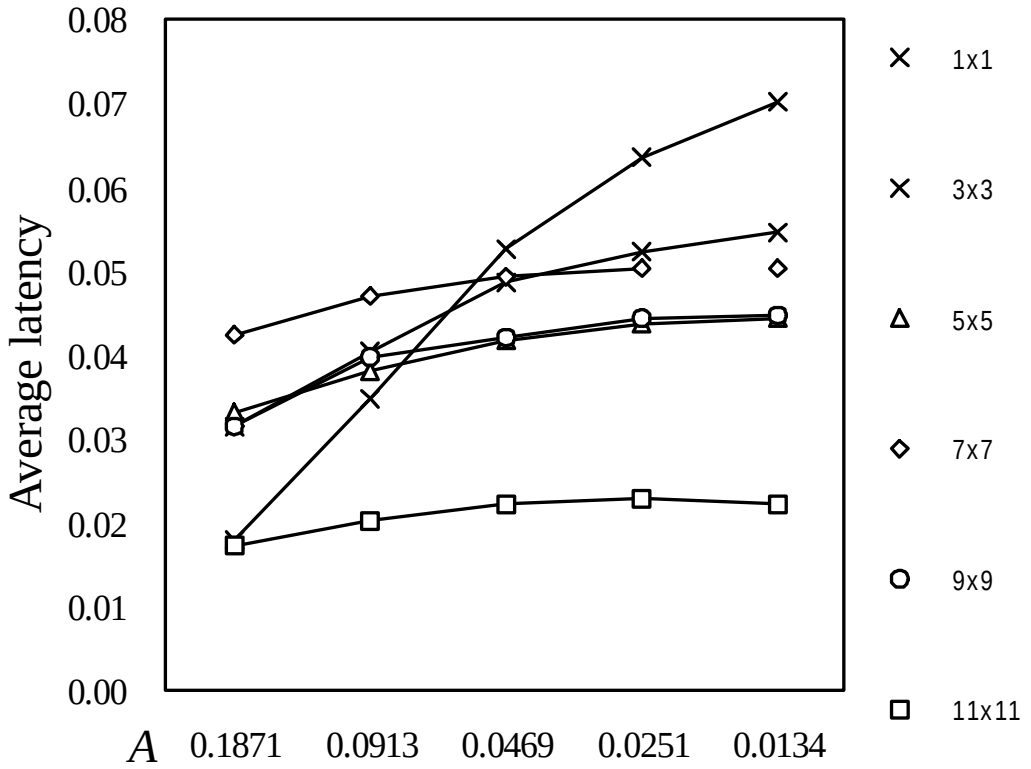


Performance of the Location-Based Scheme

- We vary A (addition coverage) from 0.1 to 0.01.
  - Smaller A means more rebroadcast.



(a)



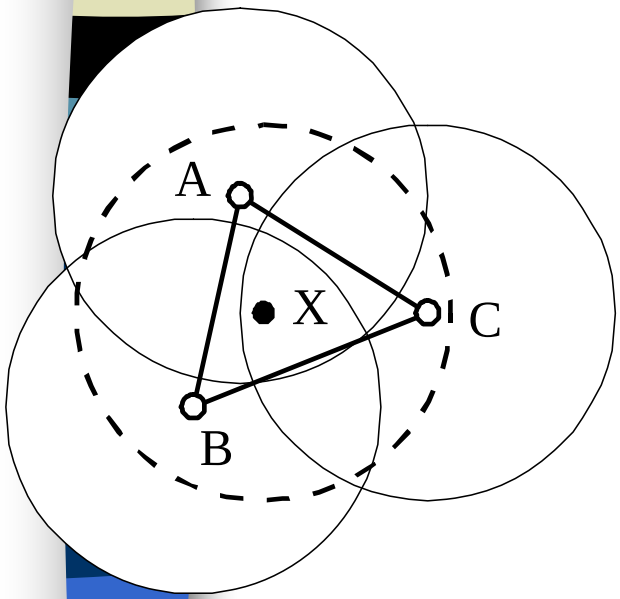
(b)

Observation

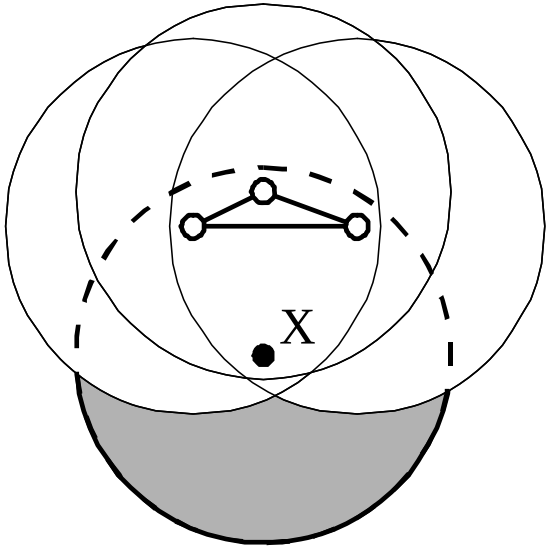
- Why choosing A=0.187?
  - This is additional coverage offered by C=2.
- Best performance over all the above schemes!

Modified Location-Based Schemes

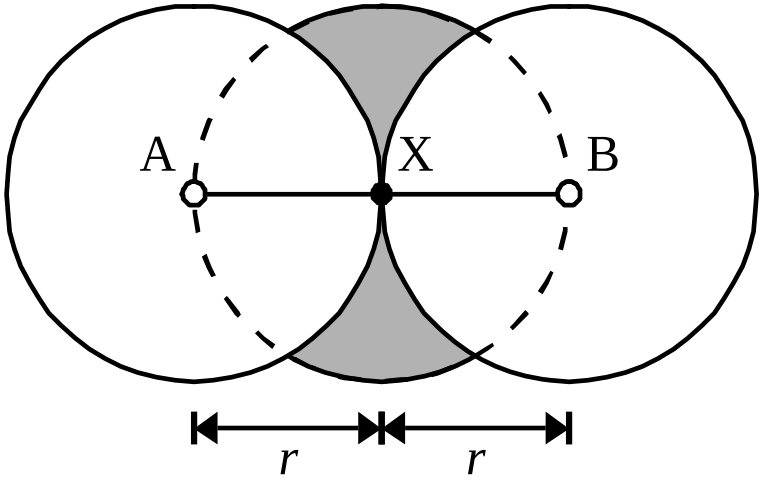
- Polygon Test:
  - If a node is within the polygon formed by the locations of senders, then DO NOT rebroadcast. (Fig. (a))
  - Otherwise, rebroadcast. (Fig. (b))
  - If a host is within the convex, the maximum additional coverage is well below 22%. (Fig. (c))



(a)



(b)



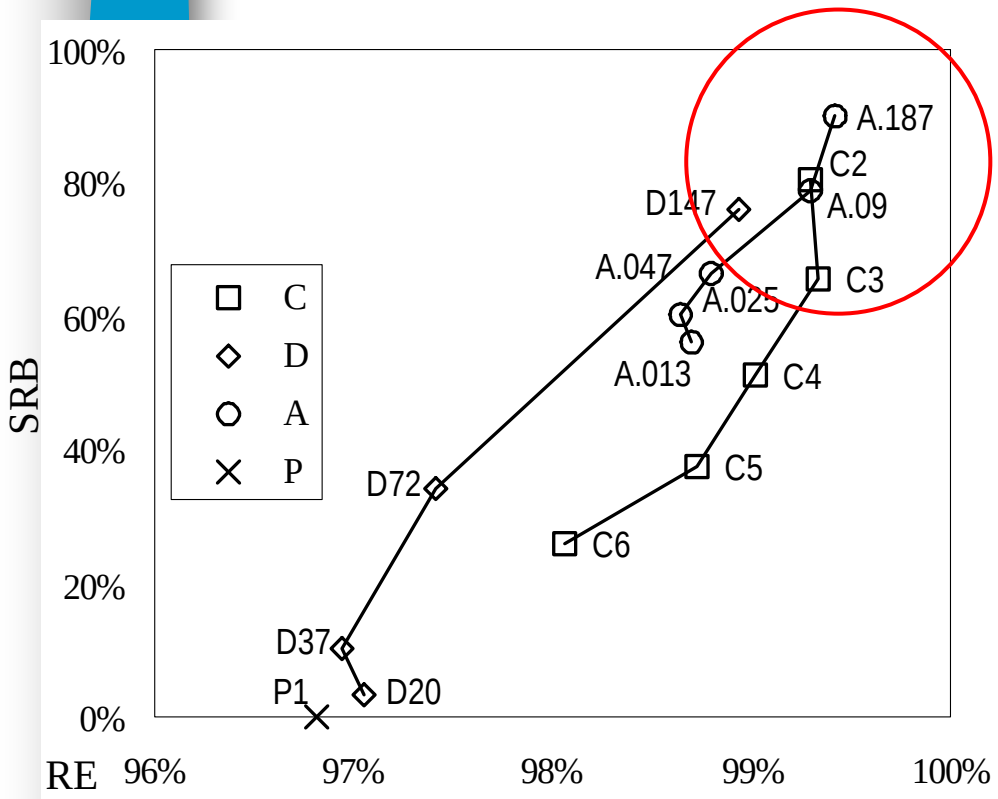
(c)

A Short Summary

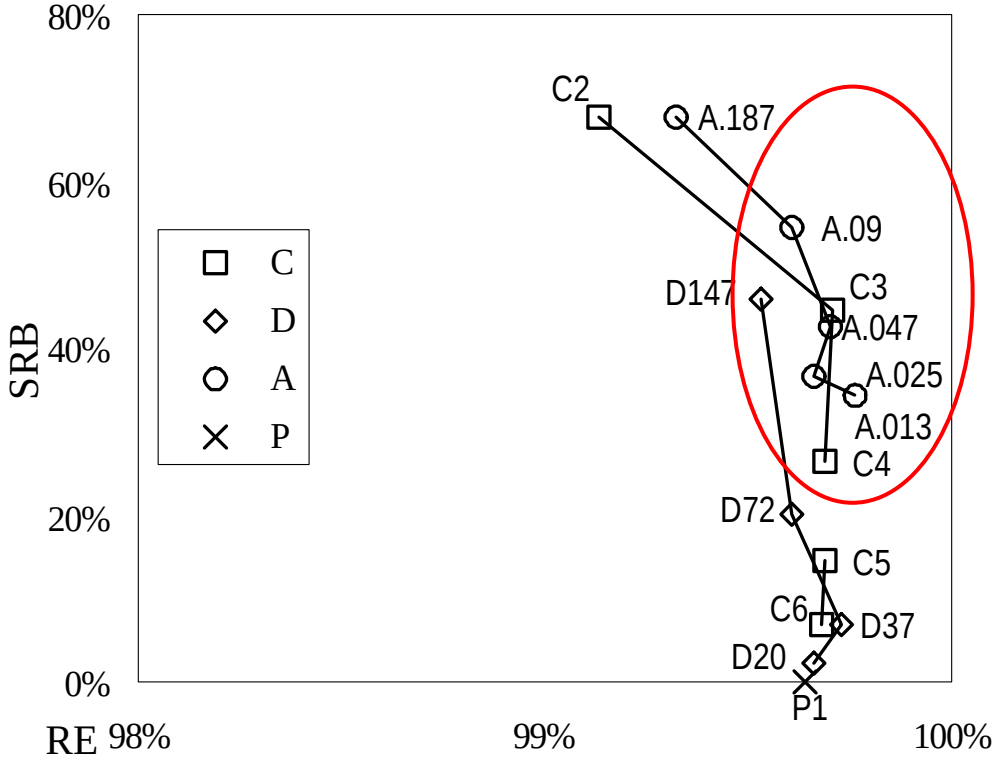
- Main Concern:
  - Extra coverage of a rebroadcast
- Different levels of accuracy:
  - probabilistic, counter, distance, location, polygon
- Performance:
  - Flooding < Probabilistic Scheme < Counter-Based Scheme < Distance-Based Scheme < Location-Based

Relationship between Reachability and Saving

- Points closer to the upper-right corner are better.

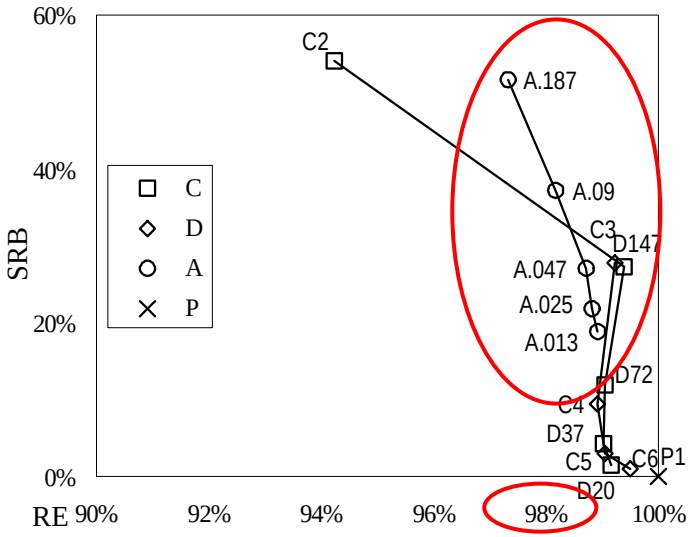


(a) 1x1 map

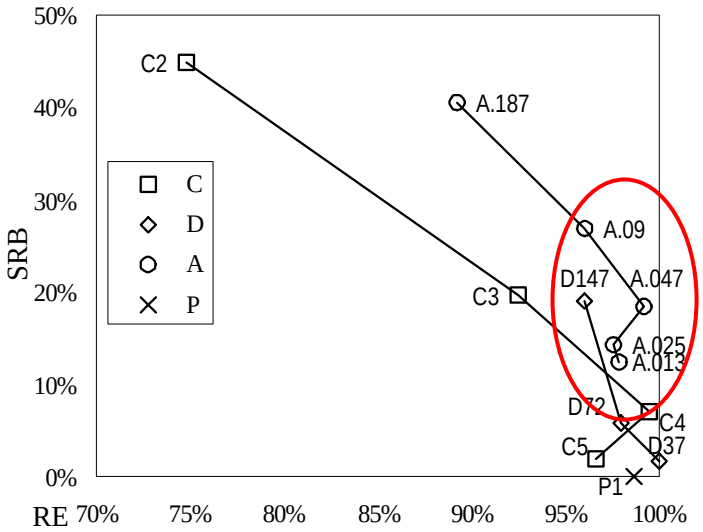


(b) 3x3 map

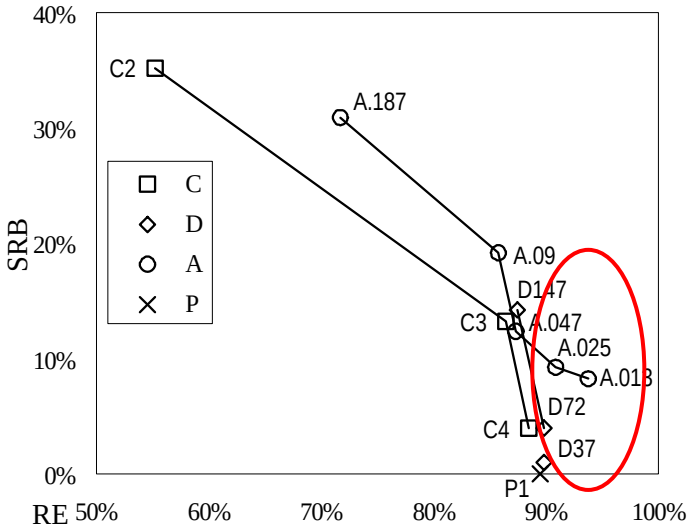
RE vs. SRB at Larger Maps



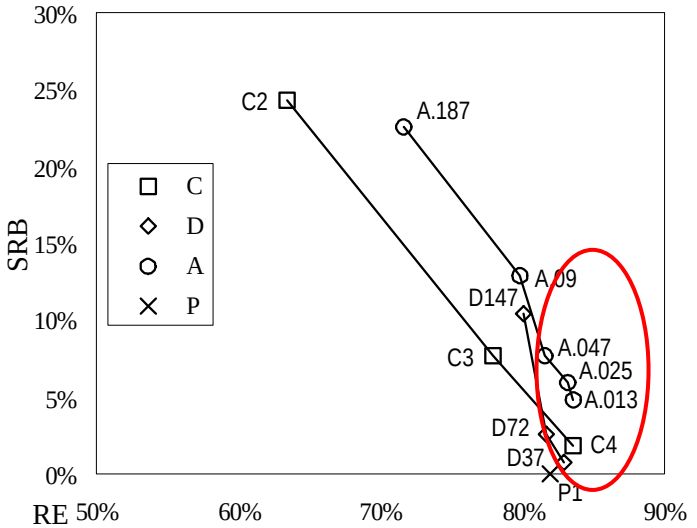
(c) 5x5 map



(d) 7x7 map



(e) 9x9 map



(f) 11x11 map

Conclusions

- Broadcast Storm:
  - a newly identified problem that could affect the performance of MANET
  - deserve more debate in the future
  - high severity:
    - redundancy, contention, collision
- Solutions:
  - based on the expected additional coverage of a rebroadcast
  - probabilistic ==> counter ==> distance ==> location

Homework #10:

1. What's the "broadcast storm" problem ?
2. How to reduce the "broadcast storm" problem ?