Broadcasting in Dynamic Graphs

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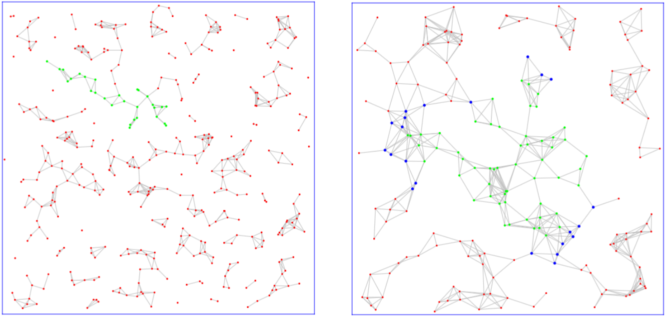


Broadcasting?

Principle

- the action of transfering something from one ”entity” to a set of entities
- *something*: information, message, virus, signal, sensation (panic), chemical molecule, etc.
- *entity*: sensor, smartphone, computer, person, car, UAV, insect, etc.

Examples of Problems

- study the evolution of the diffusion of a virus within a population
- find a strategy for broadcasting a message as fast as possible to the largest possible number of devices in a communication network

Example

Broadcasting a message in a DT-MANET

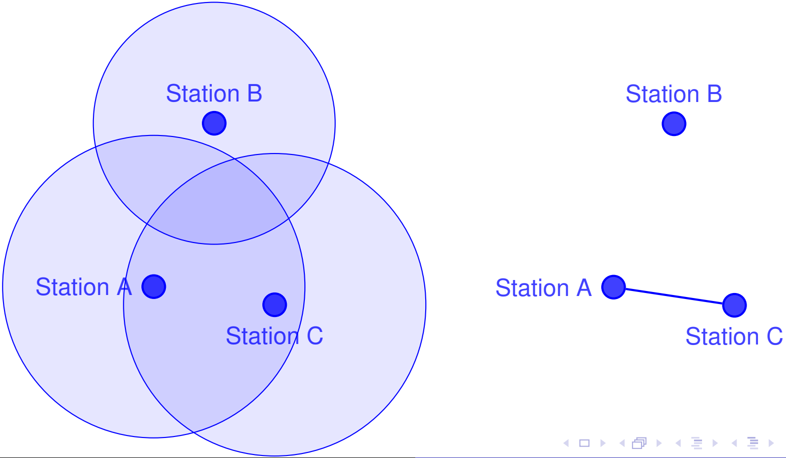
- entities are communicating mobile devices called stations
- DT-MANET: a Delay-Tolerant Mobile Ad hoc NETwork $\rightarrow$ a network not always connected

Mobile Ad Hoc Network

- stations periodically send ”Hello” packets for signaling their presence to other stations
- the signal travels up to a given maximum distance: the transmission range
- stations that receive ”Hello” packets are considered as neighbors
- since stations are supposed to be comparable (homogeneous) the communication link is supposed to be bidirectional (signal strength does not depend on the direction of the communication)
- when a station emits a message, it broadcasts it such that, without interferences, all its neighbors can receive it.

DT-MANETs

- the area covered by a station can be represented by a disk
- when two stations are within the disk of each other, they can communicate (represented by a link)



Broadcasting in DT-MANETS

Goals

- reach the maximum number of stations
- as fast as possible (in number of time steps)
- with as few message re-emissions as possible (if n devices the minimun number of emissions is $n - 1$)

Difficulties

- stations are moving $\Rightarrow$ network potentially not connected
- too many message re-emissions at the same time $\Rightarrow$ broadcast storm

Tradeoff

Goals

- reach the maximum number of stations

  $\Longrightarrow$ emission of a large number of messages
- as fast as possible (in number of time steps)

  $\Longrightarrow$ re-emission of messages
- with as few message re-emissions as possible

  $\Longrightarrow$ just the opposite

Clues

- many neighbors $\rightarrow$ should restrict the number of emissions
- sparse areas $\rightarrow$ information exchanges with neighbors are encouraged

  $\Rightarrow$ re-emission decision should depend on the neighborhood: context-aware

Classical strategies

Classification

$\longrightarrow$ Classified by Williams and Camp 2002

- Simple Flooding
- Probabilistic-based methods
- Area-based methods
- Neighbor knowledge methods

Simple Flooding

- basic algorithm
- as soon as a station receives a message, it broadcasts it, whatever the environment (dense, sparse), its neighborhood, etc.

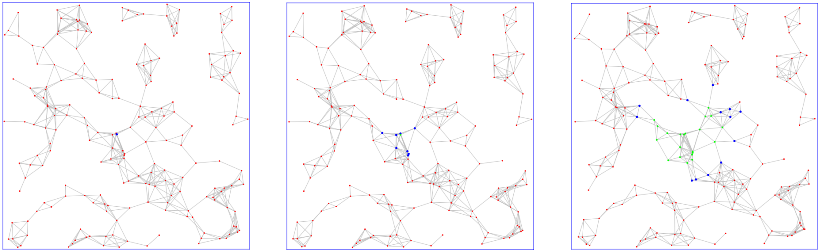
Algorithm executed by every station (except the source)

messageAlreadyTransmitted $\leftarrow$ false
while (not finished) **do**
  if message arrives **then**
    get the message
    if (not messageAlreadyTransmitted) **then**
      broadcast the message
      messageAlreadyTransmitted $\leftarrow$ true
    endIf
  endIf
endWhile

Simple Flooding

- At the begining, only one station has a message to transmit (step 0, the blue station on the images).
- As soon as it decides to send its message, it sends it, once, to its immediate neighbors (step 1 on the images).
- When neighbors receive the message, during the next time step they also transmit, once, the message to their neighbors.

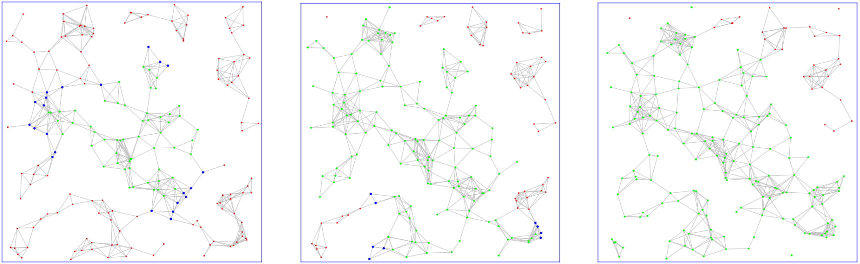
Blue stations have to transmit the message, Green stations have already transmit it and Red stations have not received the message



Step 0 Step 1 Step 3

Simple Flooding

- After a short time, many stations receive the message (step 10)
- But, some stations will never receive it (step 17)
- Why?

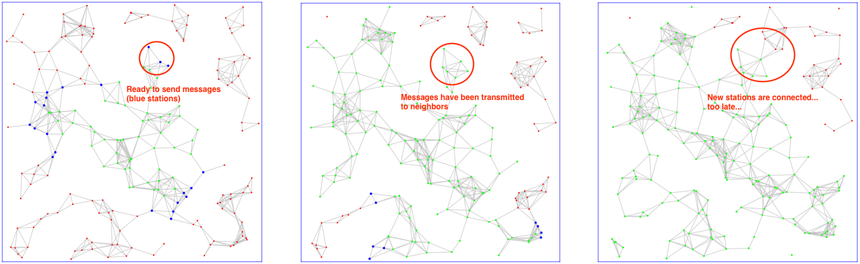


Step 4 Step 10 Step 15

Simple Flooding

Weaknesses of the strategy

- When the network is not connected, some stations will never receive the message.
- On this example, at step 4 the stations surrounded by a red circle will send their message during the next slot.
- After some additional time steps, they are connected to another connected component, but the stations have already sent their message and no more emission are planned in the strategy

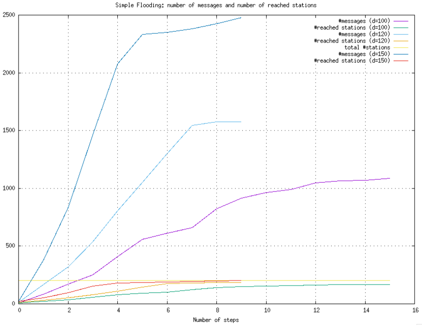


Step 4 Step 10 Step 15

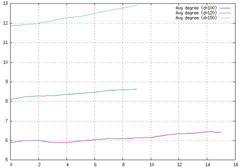
Simple Flooding

Weaknesses of the strategy

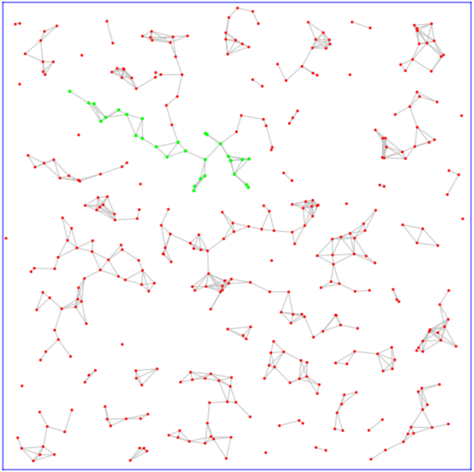
- When the network is connected, it works well, but the number of sent messages may be very large.
- Based on a one-to-one communication (while for ad hoc networks usually one msg is for all 1-hop neighbors)



- when the transmission range (d) increases, the number of messages becomes very large
- it is directly related with the average degree of the stations



Simple Flooding



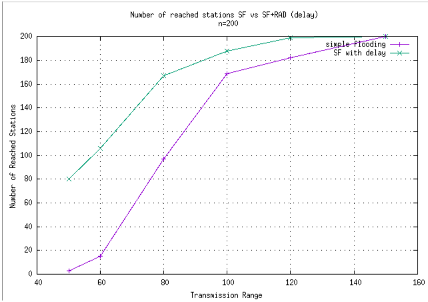
Weaknesses of the strategy

- for sparse networks the performances may be very poor
- example for $n = 300/d = 50$

$\Longrightarrow$ other strategies would be welcome

Simple Flooding with Delay

- At the begining, only one station has a message to transmit (step 0, the blue station on the images).
- After a Random Assessment Delay (RAD) it decides to send its message, it sends it to its immediate neighbors (step 1 on the images).
- When neighbors receive the message, they also transmit it message to their neighbors after a randomly chosen delay .

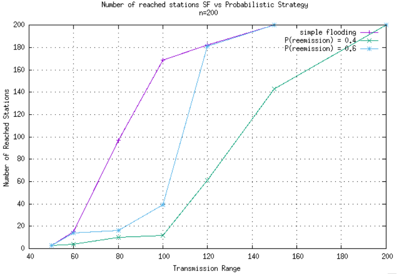


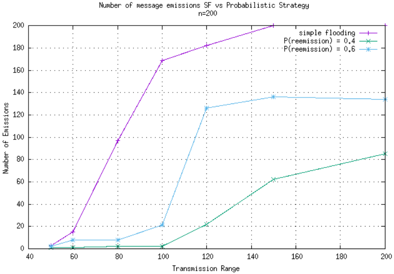
Analysis

- for sparse environments, the strategy including a delay has much better performances
- in sparse environments network is not connected $\Rightarrow$ several connected components
- the delay allows stations to carry the message towards non initially connected components

Probabilistic-based strategies

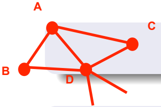
- stations rebroadcast the message with a predetermined probability
- in another strategy, the probability of re-emitting a message depends on the number of times it was received by the station (counter-based). Upon reception of a message, after a delay, a rebroadcast decision is taken.





- sparse environments: adding a RAD is good for reaching more stations
- dense environments: choice of a subset of stations for reemission save communications

  $\longrightarrow$ choice is the key point



N(A) = {B,C,D,E..} N(B) = {A,D,E..}

Node B knows that nodes D, E… already received the message
it can make the difference between N(A) and N(B) to estimate the max number
of new nodes reached by its own emission.

Neighbor Knowledge Methods

- Stations have the knowledge of their neighbors (either at 1 or 2-hops)
- the message contains in the header the identifiers of the neighbors of the sender
- if the receiver's neighbors list is not "different enough" from sender's list it does not transmit the message
- examples of such strategies: Flooding with Self-Pruning or Scalable Broadcast Algorithm (see article Williams and Camp 2002)

Area-based methods

- If a station receives a message from a geographically close station (a few meters), reemitting the message may reach only few additional stations.
- If the distance between sender and receiver is close to the transmission range, a reemission is likely to reach new stations.
- Such strategies only consider geographical information, but they may be coupled with neighborhood-based information and/or adding RAD for improving the process.

Some References

- Williams, B., & Camp, T. (2002, June). Comparison of broadcasting techniques for mobile ad hoc networks. In Proceedings of the 3rd ACM international symposium on Mobile ad hoc networking & computing (pp. 194-205).
- Peng, W., & Lu, X. (2001). AHBP: An efficient broadcast protocol for mobile ad hoc networks. Journal of computer science and technology, 16(2), 114-125.
- Hogie, L., Bouvry, P., Seredynski, M., & Guinand, F. (2006, April). A bandwidth-efficient broadcasting protocol for mobile multi-hop ad hoc networks. In International Conference on Networking, International Conference on Systems and International Conference on Mobile Communications and Learning Technologies (ICN-ICONS-MCL'06) (9 pages). IEEE. DFCN: Cumulative Neighborhood