Broadcasting in geometric radio networks

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Introduction

Non-Centralized Broadcasting

- A source node wishes to send a message to everyone
- The set of nodes isnt known a-priori
- Algorithm advances in synchronous rounds
- How many rounds are needed to broadcast?
- How to tell when everyone got the broadcast?
- Minimal time of $\Omega(D)$ rounds

Introduction

Problem Domain

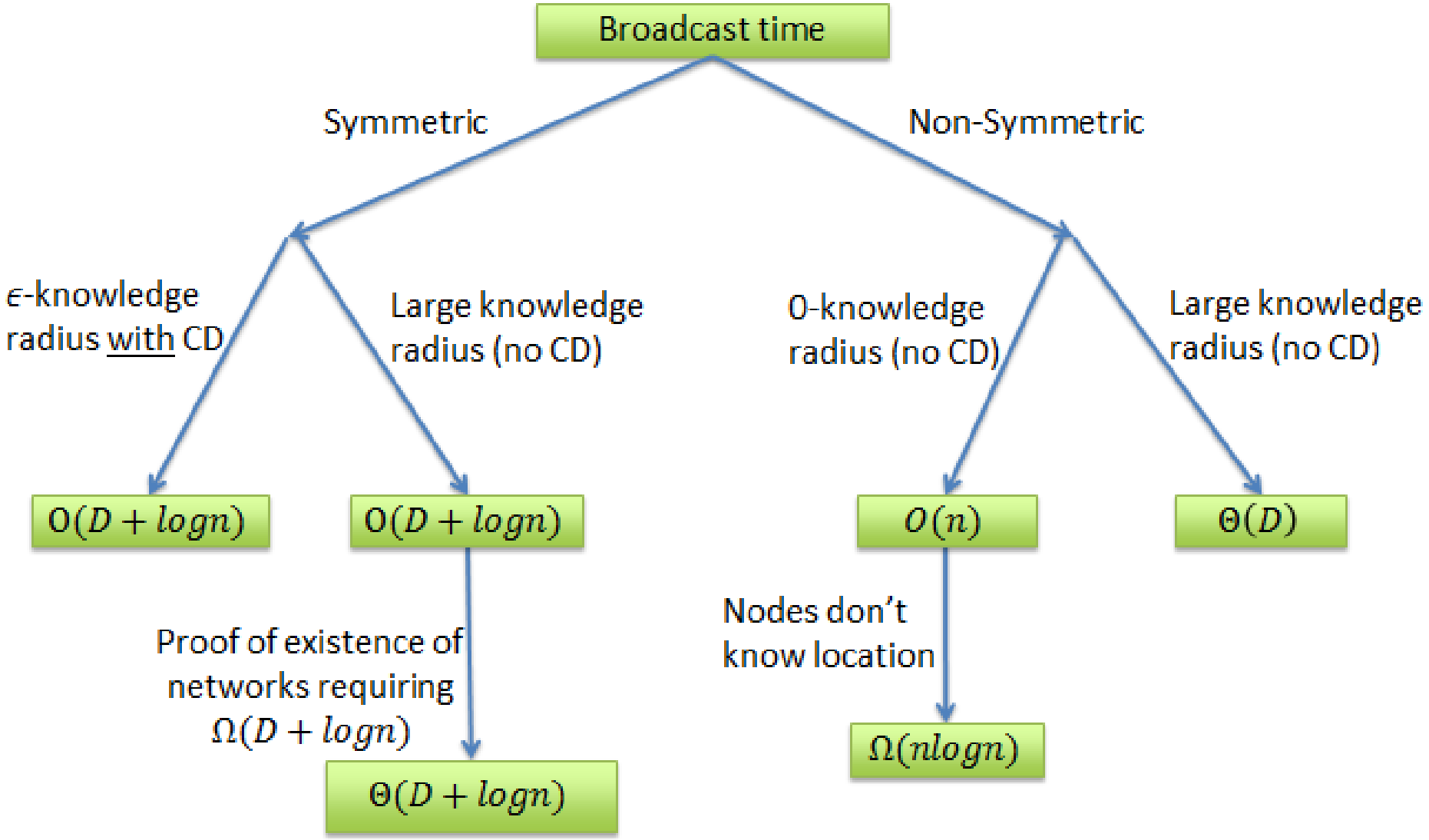
- Omni-directional antennas
- Each nodes holds: location, label, range
- Node data isnt known a-priori
- The set of available ranges is known
- The effect of knowledge radius is examined

Introduction

Previous Work

- Most algorithms assume full knowledge
- Deterministic neighborhood-knowledge algorithms require $\Omega(n)$ rounds
- Previous statement is false
- Best 0-knowledge algorithm achieved $O(nlog^2D)$

Spoiler Alert

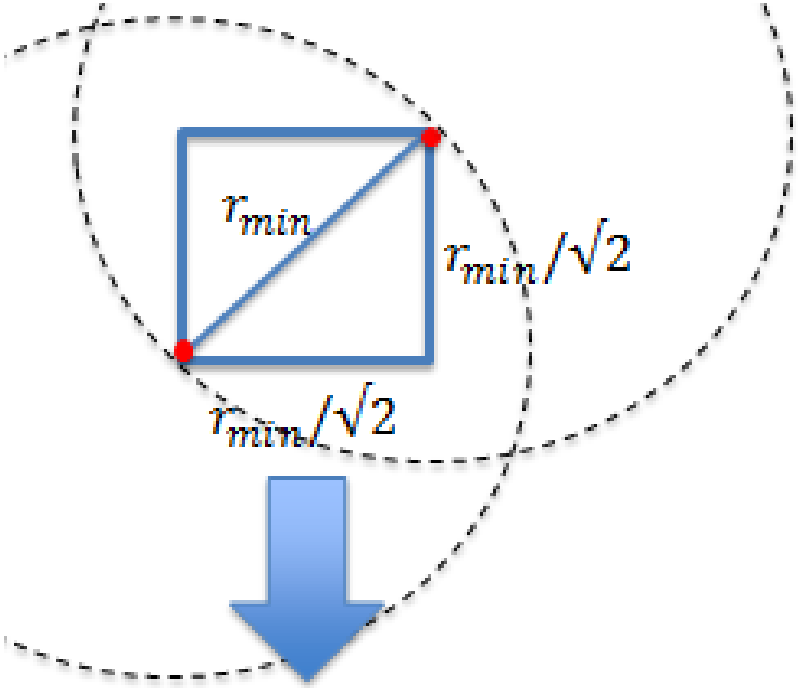


Non-symmetric large knowledge radius

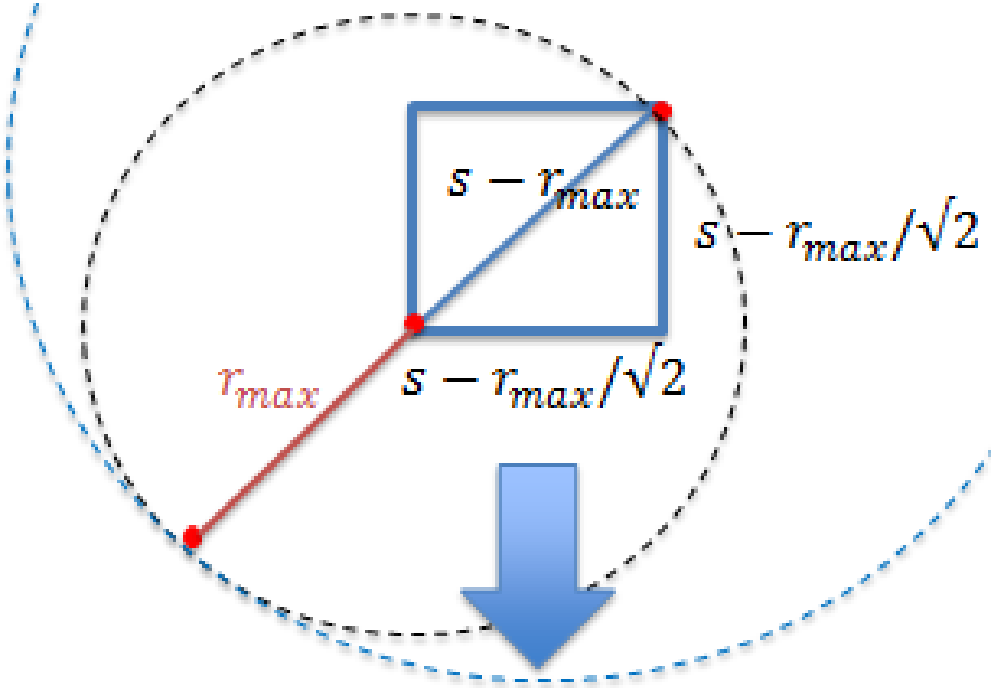
Proposed Algorithm

- Minimal and maximal transmission ranges r_{min}, r_{max} are known
- Fixed knowledge radius $s > r_{max}$
- An $O(D)$ algorithm is proposed:
  1. Plane is partitioned into squares of side $z = min(r_{min}, s - r_{max})/\sqrt{2}$ named "tiles"
  2. Tiles are grouped as blocks
  3. Tiles transmit to other tiles of the block in an organized fashion

Non-symmetric large knowledge radius: Tile Size



Any 2 nodes are within each other's range



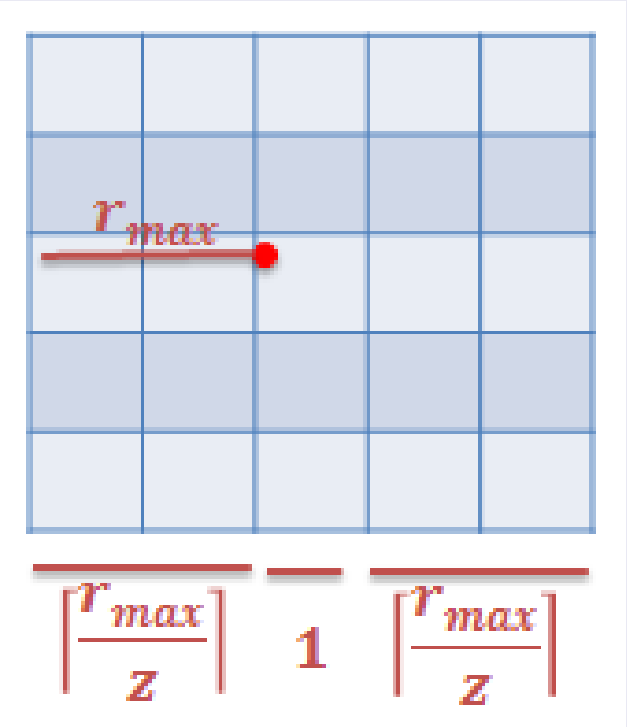
All nodes within the range of a tile's node are known to all the tile's nodes

Tile side $z = \min(r_{min}, s - r_{max})/\sqrt{2}$

Non-symmetric large knowledge radius

Block Grouping

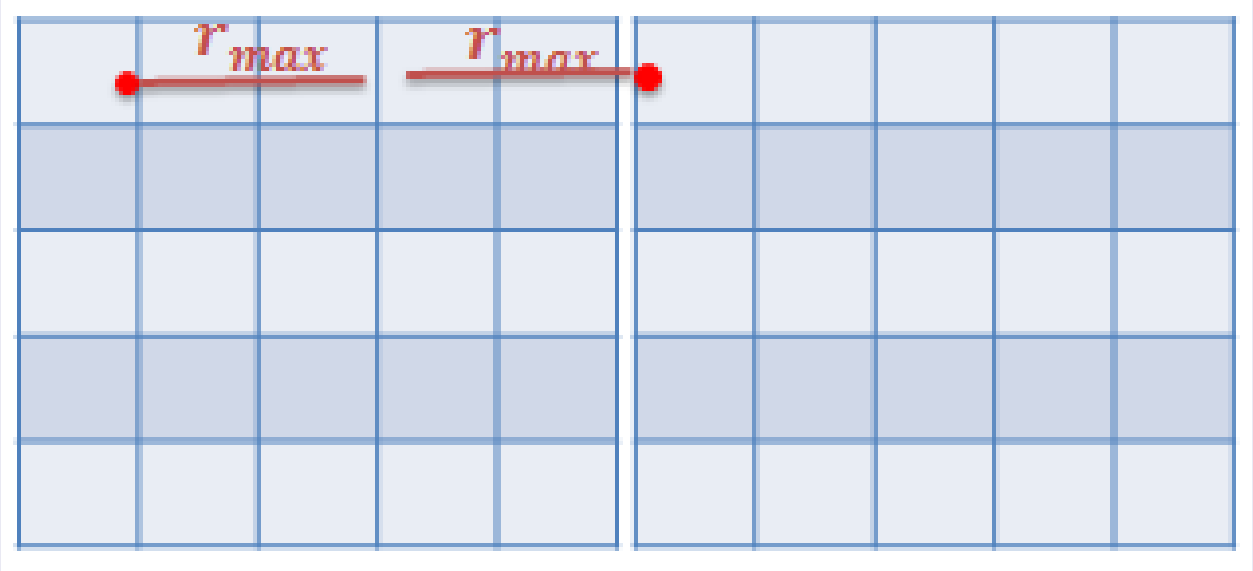
- Tiles are grouped to non-overlapping blocks of $x \times x$ tiles where $x = 2\lceil \frac{r_{max}}{z} \rceil + 1$



- Nodes in the central tile of the block cannot reach outside of the block

Non-symmetric large knowledge radius

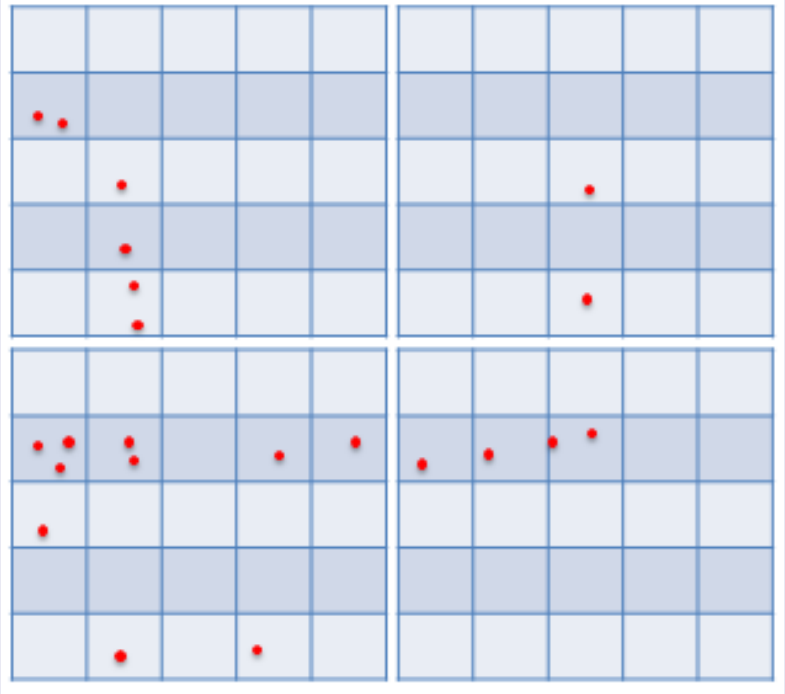
Simultaneous Transmission



- Corresponding tiles in 2 adjacent blocks will never collide

Non-symmetric large knowledge radius

Phase Rounds



For each tile pair (t, j) (and for all the blocks simultaneously):

1. If t is in state *uninformed* or has been *informed* for an entire phase, do nothing. Else, transmit by label
2. If j is in state *uninformed*, the smallest node to get that message transmits. Tile j becomes *informed*

Non-symmetric large knowledge radius

Observations

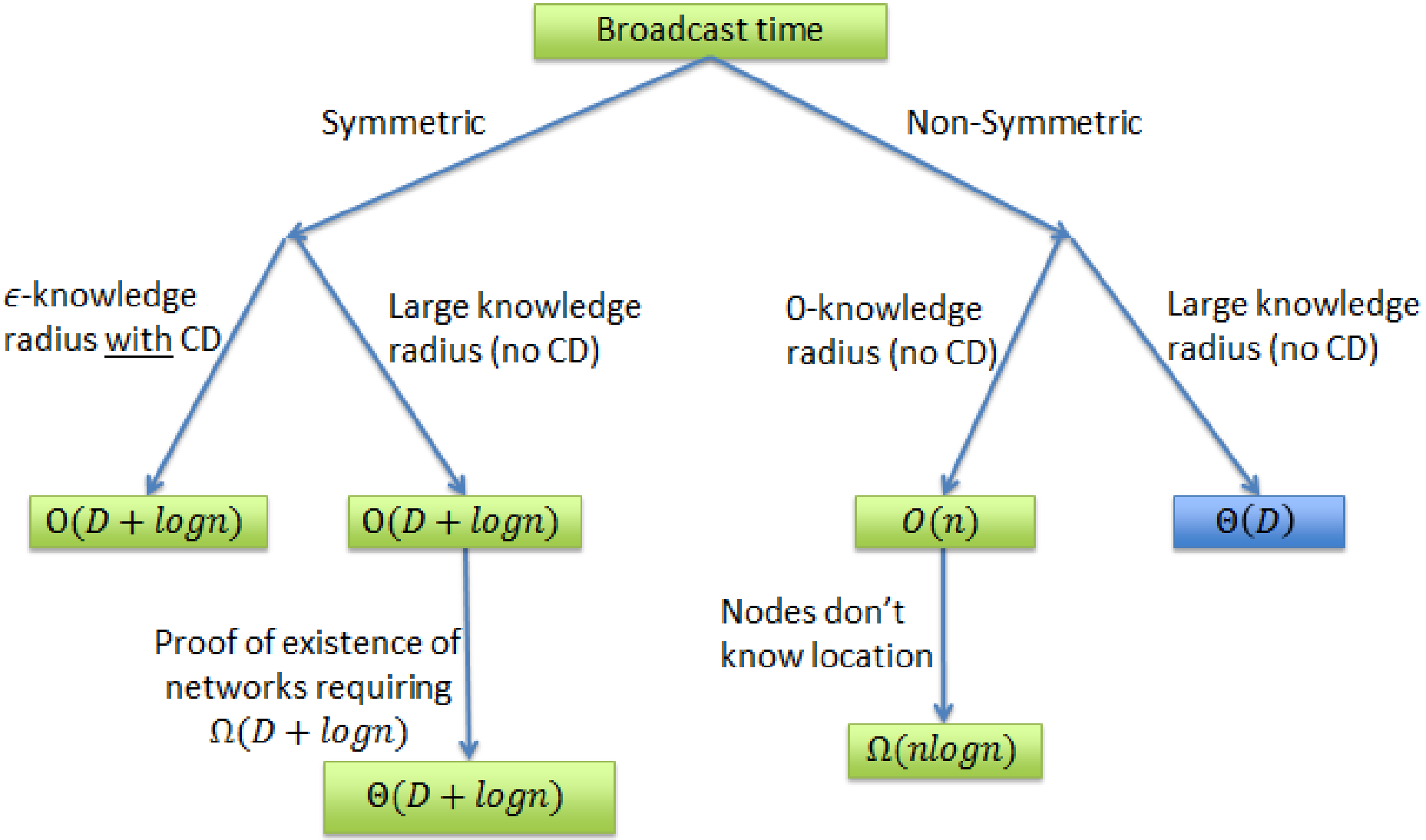
- Each phase consists of $y = x^2(x^2 - 1)$ steps of 2 rounds. y is constant
- By the choice of tile side nodes have enough knowledge to decide whom submits

Proof

1. Given a node v in tile T, since it first hears the message, after at most y rounds, T becomes *informed* (since v is in the range of some node from the tile this message comes from)
2. A tile T' with nodes in the range of v becomes *informed* after at most y rounds
3. Therefore, v gets the message and after at most $2y$ steps all nodes in v's range get the message

- Broadcast is completed in $O(D)$, which is also $\Theta(D)$

What's next?


Broadcast time
Symmetric
Non-Symmetric
ϵ-knowledge radius with CD
Large knowledge radius (no CD)
0-knowledge radius (no CD)
Large knowledge radius (no CD)
$O(D + logn)$
$O(D + logn)$
$O(n)$
$\Theta(D)$
Proof of existence of networks requiring $\Omega(D + logn)$
Nodes don't know location
$\Omega(nlogn)$
$\Theta(D + logn)$

Non-symmetric 0-knowledge radius

0-Knowledge drawbacks

- Fixed knowledge radius $s = 0$
- Consequences of 0-knowledge radius:
  1. Nodes have no knowledge of other nodes in the same tile
  2. Nodes of a tile no longer know which nodes of another tile are accesible and by whom

Coping with the lack of knowledge

1. Solved by a preprocessing phase that attains knowledge radius r_{min}
2. Solved by changing the algorithm so that the entire area reachable form a tile is informed

Non-symmetric 0-knowledge radius

Proposed Algorithm

- Minimal and maximal transmission ranges r_{min}, r_{max} are known
- Fixed knowledge radius $s = r_{min}$ attained by preprocessing
- An $O(n)$ algorithm is proposed:
  1. Plane is partitioned as before, with tiles of side $z = r_{min}/\sqrt{2}$
  2. Tiles transmit to the entire reachable area in a different organized fashion

Non-symmetric 0-knowledge radius

Preprocessing

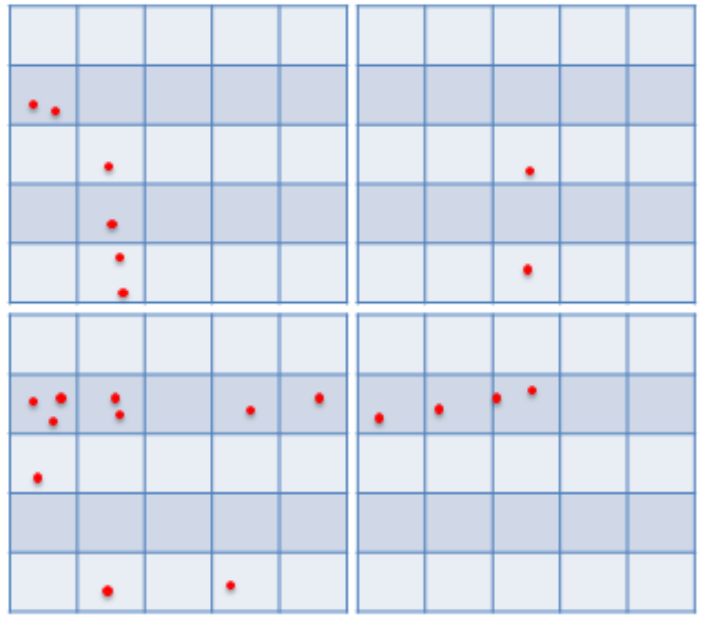
- Every node transmits its data in its turn (determined by label)
- $O(n)$
- Requires knowing n
- A modification to the algorithm is shown such that knowledge of n is not required (still $O(n)$)

Initialization

- All tile's nodes are numbered according to the labels
- Every tile is given a transmission counter initialized to 1
- Let $|T|$ be the number of nodes in tile T

Non-symmetric large knowledge radius

Phase Rounds



- For each tile i (and for all the blocks simultaneously):
  1. If tile i is *informed* and its *transmission counter* $< |i|$, a node transmits according to the *counter*
  2. For each tile $j \neq i$:
  3. If j is *uninformed* and a node received the message in (1), the lowest labeled node to receive the message transmits. Tile j becomes *informed* and *counter* is increased

Non-symmetric large knowledge radius

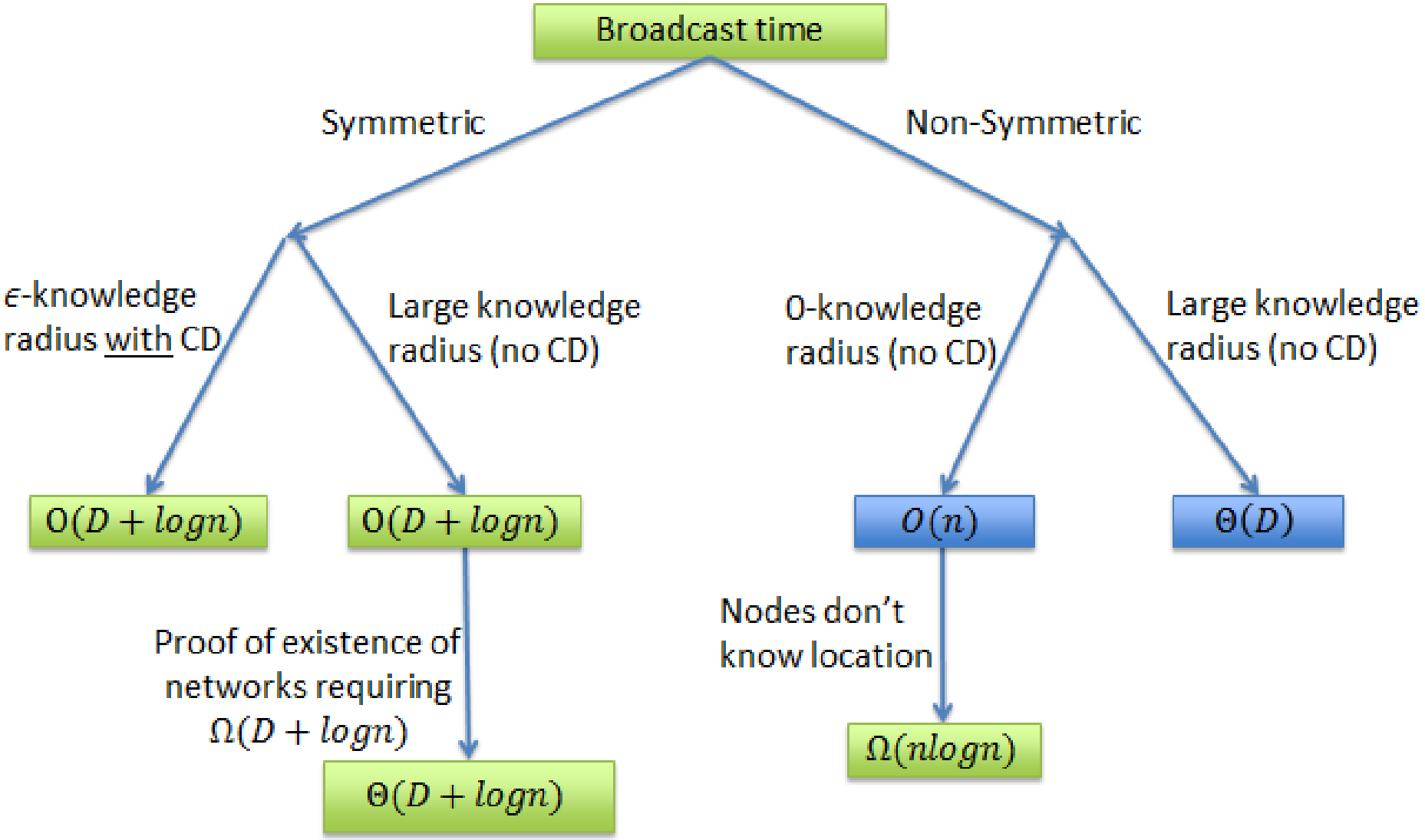
Observations

- A node that gets a message knows whom else in the node got it, and can decide who transmits

Proof

1. From the moment tile T becomes *informed* until all tiles with a node in the range of a node from T become *informed*, at most $|T|$ phases have passed
2. There is a path of length at most D from the source to any node v
3. This path corresponds to a sequence of tiles $T_1, T_2, ..., T_d, d \leq D$
4. Hence, the time required for broadcasting is $O(|T_1| + |T_2| + ... + |T_d|) \subseteq O(n)$

What's next?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Questions?