Location Services

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The papers

- A Scalable Location Service for Geographic Ad Hoc Routing
  - J. Li, J. Jannotti, D.S.J. De Couto, D.R. Karger, R. Morris; MobiCom 2000
- LLS: a Locality Aware Location Service for Mobile Ad Hoc Networks
  - I. Abraham, D. Dolev, D. Malkhi; DIALM-POMC 2004

Overview

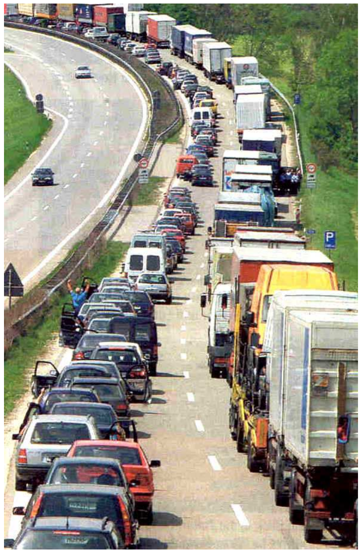
- Introduction
  - Ad Hoc Networks
  - Problem overview
- The GLS approach
- The LLS approach
- Conclusion

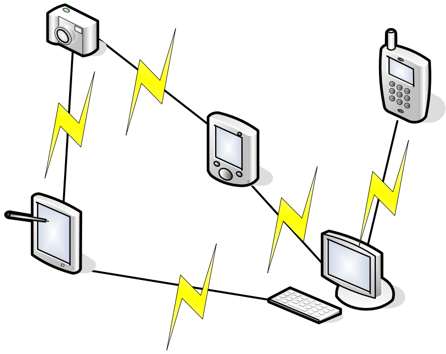
Introduction

- What is Ad Hoc?
  - connection method for Wireless Networks
  - dynamic
  - spontaneous
  - mobile
  - without any additional infrastructure (i.e. no base stations, no routers, no directories)
    - nodes themselves have to contribute to routing

Applications

- Taxi/Police/Fire squad fleet
- Wearable computing
- Disaster relief and Disaster alarm
- Military/Security
- Meeting room/conference
- ...





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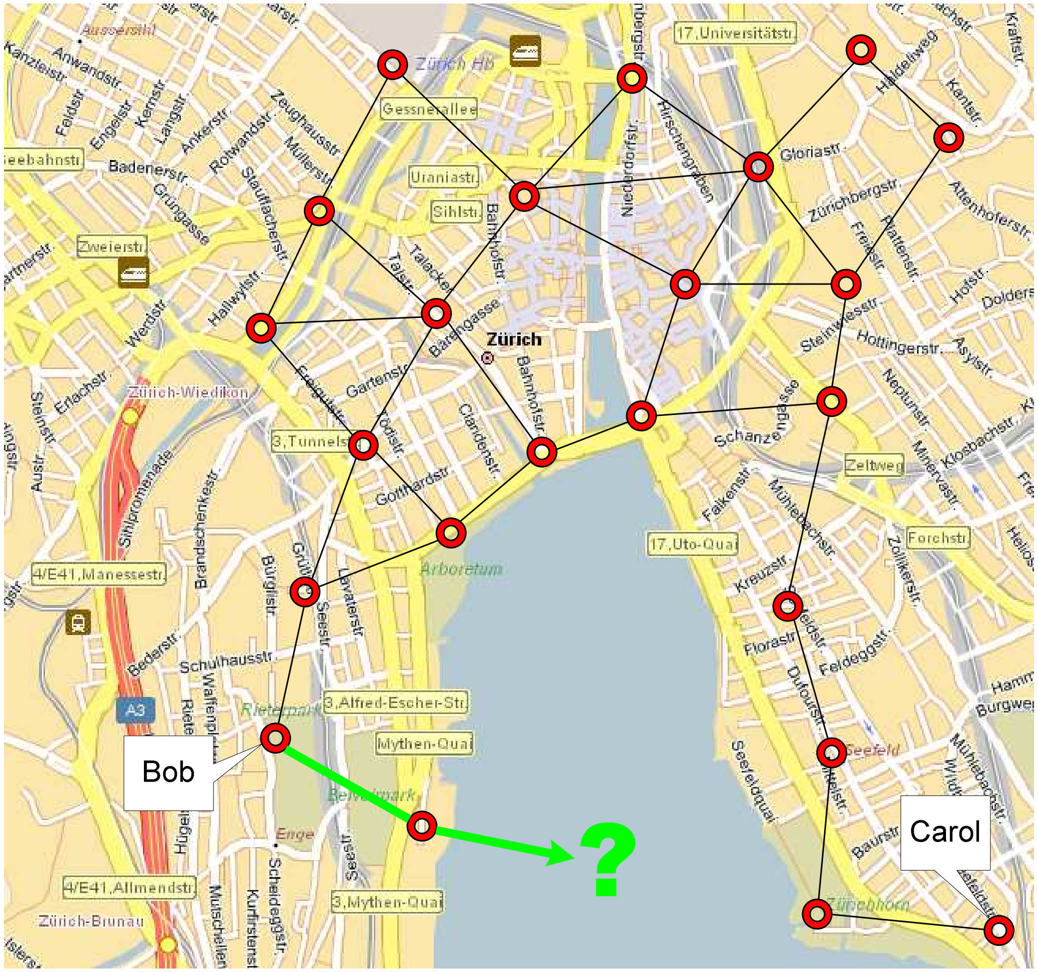
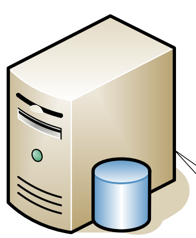


How to route in Ad Hoc Networks?

- Geographic routing algorithms assume that besides the position of the source the position of the destination is also known
- How to get this position?
  - Well known Location Server



	Latitude	Longitude
Alice	35.5446	-105.9309
Bob	43.2113	3.8892
Carol	61.2113	-45.2203
...	...	...

Ad Hoc???

Get the Position of the destination

- What do we need:
  - The network must somehow know where a node is
    - a node has to **publish** its location
  - A node must be able to find out another node's location, given its network identifier
    - a node wants to **lookup** another node's location
- A **lookup service** offers **publish** and **lookup** primitives

A simple publish-driven approach

- When a node comes up or changes its position, it simply floods the network with its new location
  - Each node has to hold information about every other node in the network
    - memory...
    - traffic...

A simple lookup-driven approach

- When a node wants to know another node's position, it simply floods the network with a query
  - The corresponding node answers with its position, also by flooding
    - no memory needed
    - even more traffic

Requirements

- No node should be a bottleneck
- The failure of a node should not affect the reachability of many other nodes
- Queries for the locations of nearby hosts should be satisfied with correspondingly local communication.
- The per-node storage and communication cost of the location service should grow as a small function of the total number of nodes.

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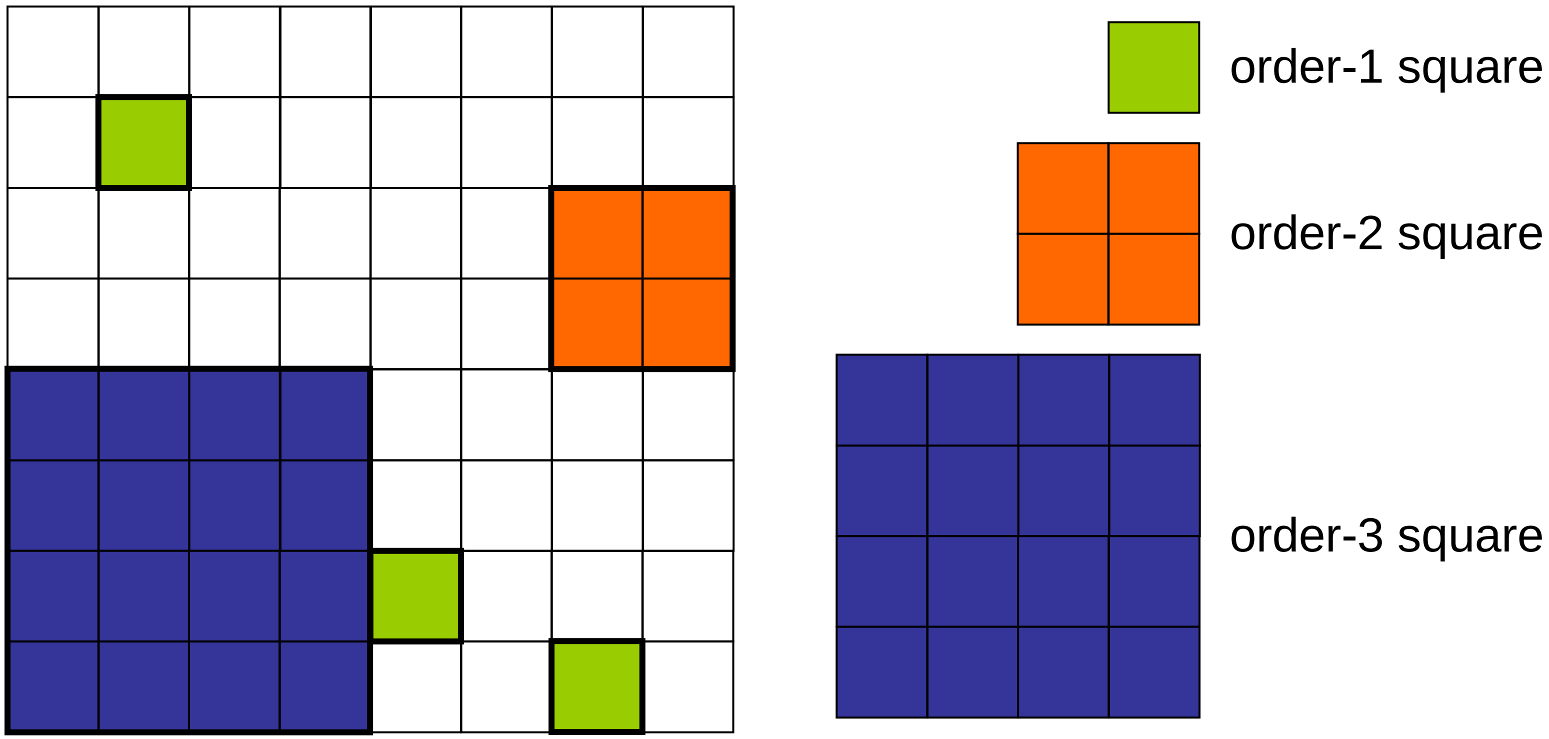
GLS – Grid's Location Service

- Each node has several other nodes as location servers and also acts as a location server on behalf of some other nodes
- GLS uses geographic forwarding
  - here: simply route towards the destination (also known as greedy routing)
  - could also be another geographic routing protocol

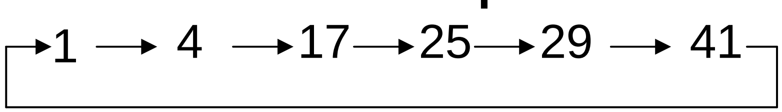
Partitioning the world



Invariant: a node is located in exactly one square of each size (no overlapping)
An order-x square contains always 4 order-(x-1) squares

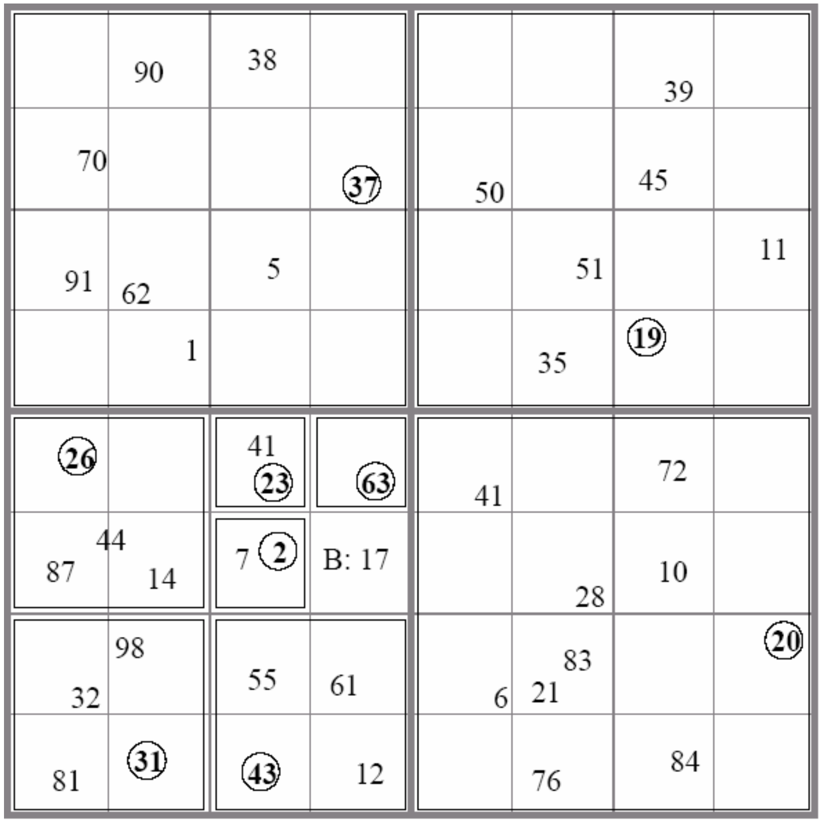
A wants to find B (lookup)

- B has ID 17 (computed through hash function known by every node)
- A sends a request to the closest node to B (ID 17) for which A has location information. Next node does the same... Until B is reached.
- ***Def.:*** Node **closest** to B in ID space: node with least ID greater than B
- Circular ID space:



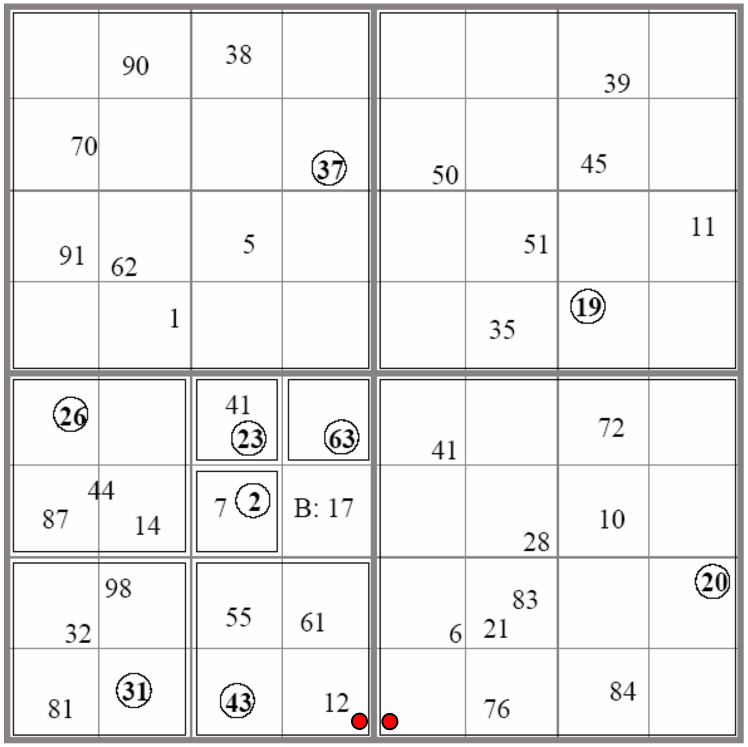
B publishes its location

- B (ID 17) chooses three location servers for each level of the grid hierarchy in its related squares
- B recruits nodes with IDs “close” to its own ID to serve as its location servers



Problems...

- Works fine for uniform distributed nodes over the whole area
- neighboring points over border?
- mobility?



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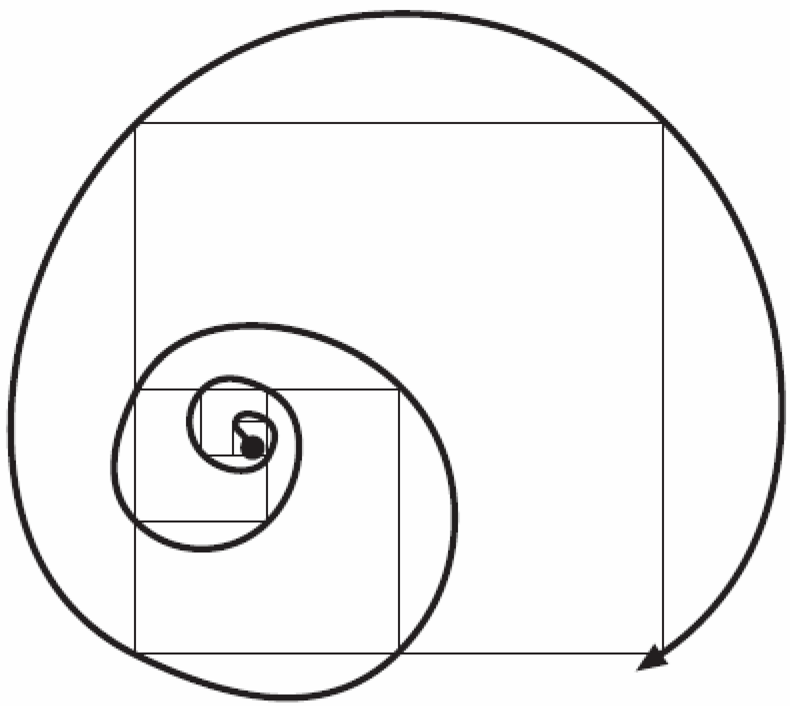
LLS – Locality-aware Location Service

- Locality-aware publish algorithm:
  - Cost of updating the location service due to a node moving from x to y is proportional to the distance between x and y.
- Locality-aware lookup algorithm:
  - Cost of a lookup operation is proportional to the cost of routing between source and target when the destination is known.

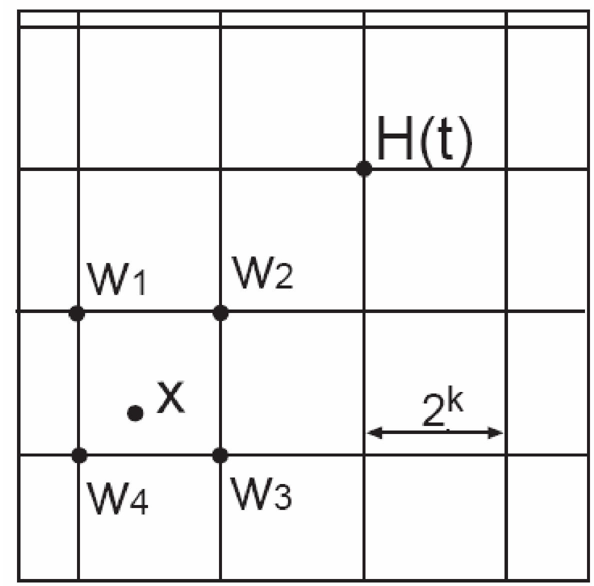
How it works – The spiral algorithm

- lookup: perform a spiral like search path
- a node publishes its location information in a set of virtual points that form a virtual spiral
- the lookup finds the location of the destination where the two spirals intersect



Why do the spirals intersect?

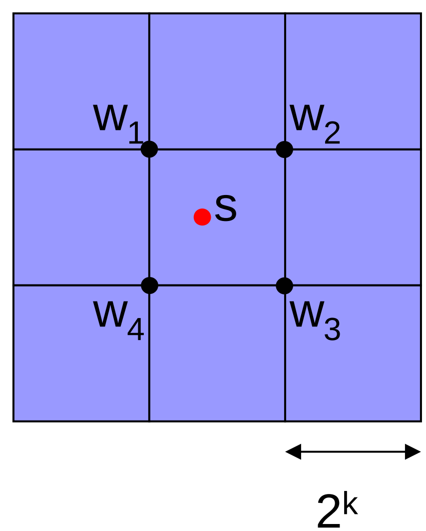
- Hierarchy of lattices with squares of size 2^k x 2^k and H(node ID) as its origin
- When a node t performs a publish, it aligns its lattices to H(node ID of t) and stores its location information to the 4 lattice points that are closest to t (for each hierarchy-level)
- When another node wants to find out the position of t, it performs a lookup, aligned to H(node ID of t)



$W_k(t.id,x) = \{w_1, w_2, w_3, w_4\}$

Why is it locality-aware?

- Lemma: Let k be the minimal index such that $|st|=d<2^k$ then at least one of the nodes in W_k(t.id,s) contains a location pointer to node t



in the k-th phase

Why is it locality-aware?

- Theorem: For networks in which routing is Δ-locality-aware, for any source s and destination t the expected cost of locating t is O(|st|)

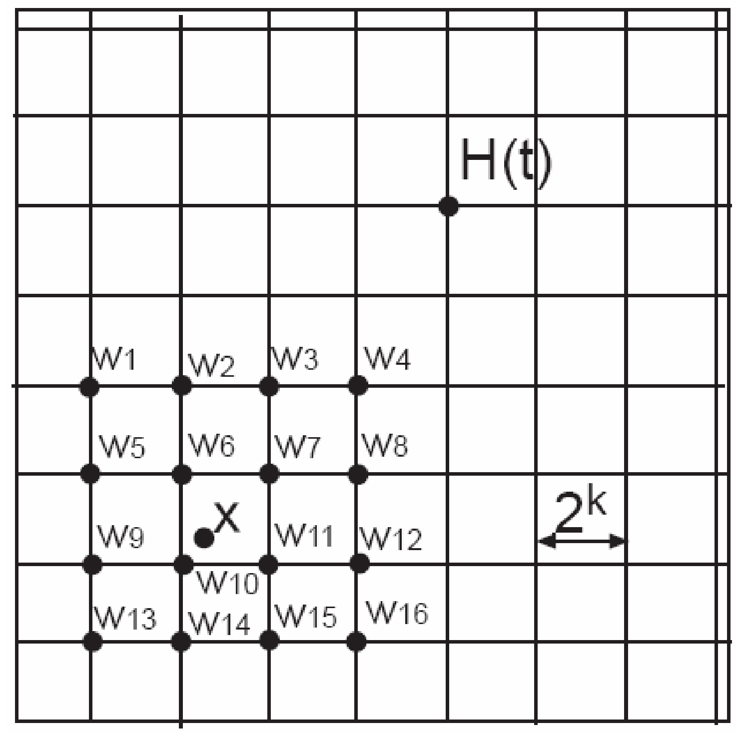
$$\Sigma_{i \le k} 2 \cdot 4 \cdot 2^i \cdot \Delta = O(2^k) = O(|st|)$$

The spiral-flood algorithm

- Problem in the basic spiral algorithm: path cost from source to destination is low, but cost from source to first virtual point is high
- Solution (spiral-flood algorithm): do spiral lookup as long as the cumulative cost is less than 4^{phase}, then flood with depth 2^{phase}

The LLS algorithm

- At each level, publish to 16 virtual points instead of only 4
- Instead of publishing the location in Z_i, publish pointers to W_{i-1}. Store the location only in Z_0



$Z_k(t.id,x) = \{w_1,\ldots, w_{16}\}$

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- Privacy?
- Own position always known?