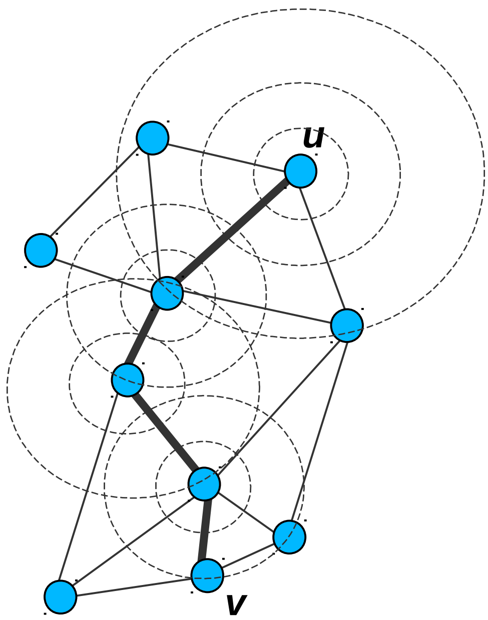
Topology Control

Topology Control

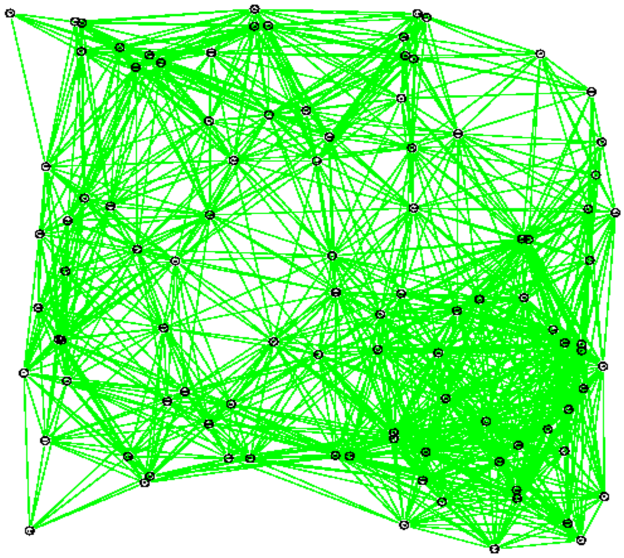
- Sparse topologies, low node degree
  - Storage complexity, storage efficiency
- Short paths, low energy paths
  - Energy: battery life time
    health issues
    (high frequency radiation)
- Low load
- Efficient distributed construction and maintenance
  scalability
  fault tolerance
  self-reconstruction



Topology Control

Example: no topology control

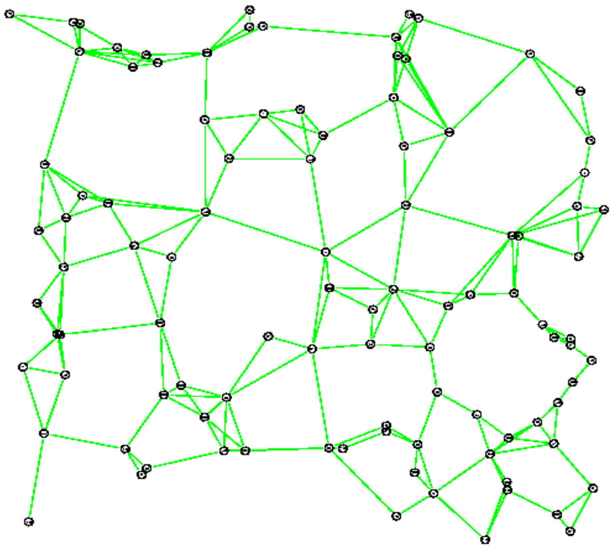
Maximum transmission distance *R*



- High energy consumption
- High amount of interference
- Low throughput

Topology Control

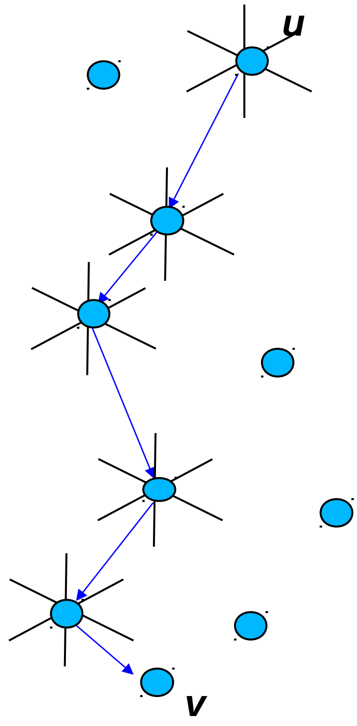
Example, using topology control



- Global connetivity
- Low energy consumption
- Low amount of interference
- High throughput

Position Based Routing

- The packages are forwarded „on the fly” to the next node based on the geographic position of
  - the current node,
  - the neighbors of the current node,
  - the destination node
- Routing table is not needed
  - Storage efficiency, low update costs
- Particularly suitable for networks, where
  - the nodes are moving with high velocity
  - topology changes are frequent
- Inherent, immediate support of geocasting
  - routing into a geographical region
  - routing to node(s) close to a given geographic position
- How the position of the destination can be detected?



Distributed Location Services

Location service: provides position information for a requested node

Problems with centralized solutions:

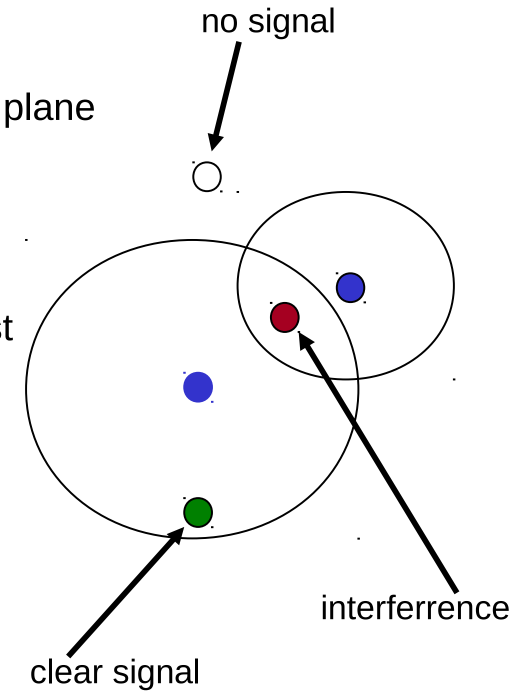
- Each node must know the position of the location servers, i.e. nodes that provide the location service (a chicken-egg problem)
- Very high amount of traffic on the location servers and nodes in their environment

Desired properties of distributed location services

- Load is balanced over rhe nodes
- Low storage and communication costs
- Short paths for the position queries
- Fault tolerance

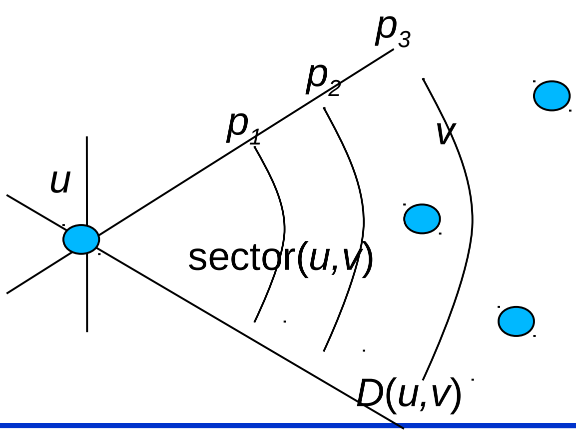
A simple physical model of networks

- Homogeneous network
  - consisting of n wireless nodes $s_1,..,s_n$ in the plane
- Wireless transmission
  - One frequency (one channel)
  - Adjustable transmission range
    - Maximum transmission distance at least maximum distance between nodes
    - Inside the range of the sender: clear signal, or interferrence
    - Outside of the range: no signal
  - Communication packets have unit size



Hardware Model

- Adjustable transmission power
- *k* antennae per node for sending and receiving
  - work simultanously, independently from each other
  - define sectors



Graph Model

Definitions: Let V be a set of n nodes in the plane and $G=(V,E)$ a graph

- G is a ***c*-spanner**, if $\forall\, u,v \in V\ \exists$ a path P from u to v, such that $\|P\|_2 := \sum_{e\in P} \|e\|_2 \le c\, \|u,v\|_2$

- G is a **weak *c*-spanner**, if $\forall\, u,v \in V\ \exists$ a path P from u to v, such that P is contained in the disk with radius $c\, \|u,v\|_2$ centered at u.

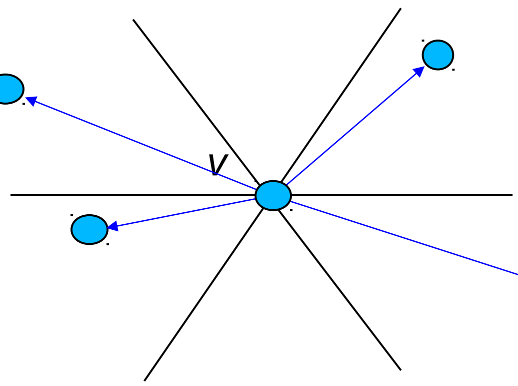
- G is a **(*c*,*d*)-power spanner**, if $\forall\, u,v \in V\ \exists$ a path P from u to v, $P = (u=u_1, \ldots, u_m=v)$, such that

$$\sum_{i=1}^{m-1} (\| u_i, u_{i+1} \|_2)^d \le c \cdot \min_{(u=v_1,\ldots,v_m=v)} \sum_{i=1}^{m-1} (\| u_i, u_{i+1} \|_2)^d$$

- G is a **power spanner**, if for any $d > 1$ there is aconstant c, such that G is a (c,d)-power spanner.

Topologies

Yao graph [Yao 82]: For each node $v \in V$ the plane is partitioned into into sectors of equal angle $\theta \le \pi/3$



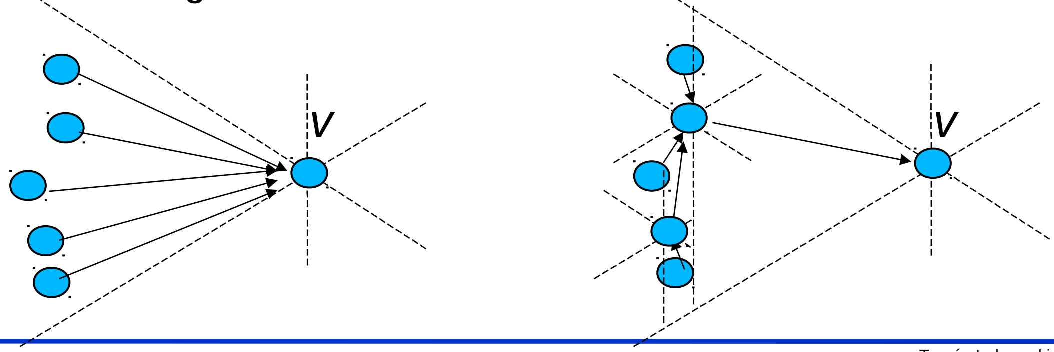
Each node is connected to the closest node in each sector -- if any -- with a directed edge:

$E := \{(u,v) \mid \forall\, w \ne v : \text{sector}(u,v) = \text{sector}(u,w) \Rightarrow D(u,v) < D(u,w)\}$

Topologies

Let G_Y be the Yao graph.
The **bounded degree Yao graph (BoundY)** [Arya et al. 95] is defined by the following procedure:

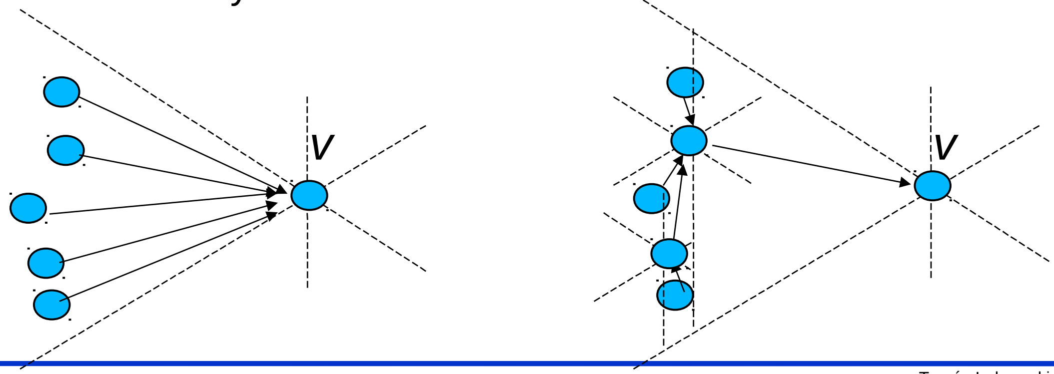
- <u>For each</u> $v \in V$ and <u>for each</u> sectors around v <u>do</u>
  - $N(v)$:= { w | $(w,v) \in E(G_Y)$ and $w \in$ sector(v) }
  - Replace the star { (w,v) | $w \in N(v)$ } with a certain tree of constant degree



Topologies

Bounded degree Yao graph (cont.):
Replacing the star with a tree with root v

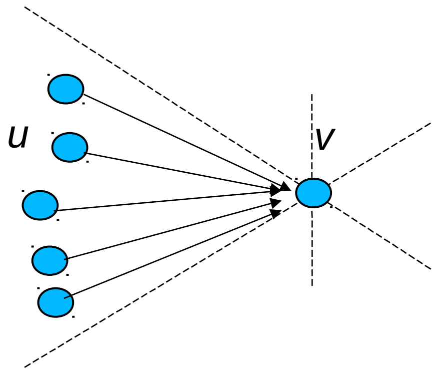
- Let $N(v)$:= { w | $(w,v) \in E(G_Y)$ and $w \in$ sector(v) }
- Let $v' \in$ N(v) be the closest node to v
- Connect v' to v with a directed edge
- Partition the plane around v' into sectors of angle θ
- <u>For each</u> sector around v' <u>*do*</u>
  - Recursively build the tree with root v'

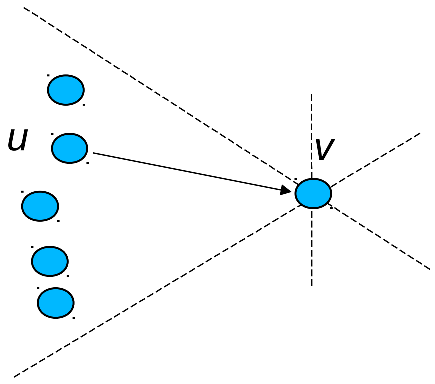


Topologies

Let G_Y be the Yao graph.
The **Sparsified Yao graph (SparsY)** [Li et al. 01] is defined by the following set of directed edges:

$$E := \{ (u,v) \in E(G_Y) \mid \forall\, w : (w,v) \in E(G_Y) \text{ and } \text{sector}(v,w) = \text{sector}(v,u) \Rightarrow D(v,u) < D(v,w) \}$$

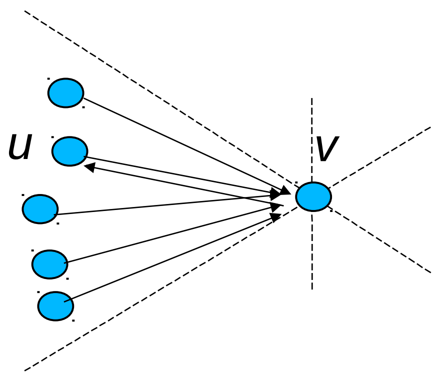


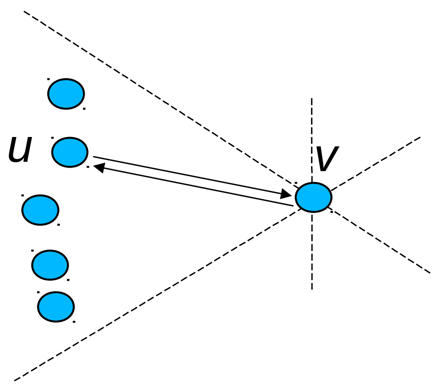


Topologies

Let G_Y be the Yao graph.
The **Symmetric Yao graph (SymmY)** [Li et al. 01] id defined by the following set of directed edges:

$$E := \{ (u,v) \in E(G_Y) \mid (v,u) \in E(G_Y) \}$$

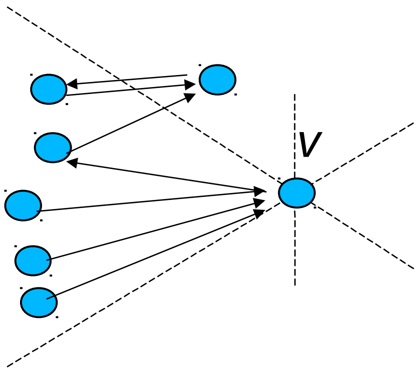


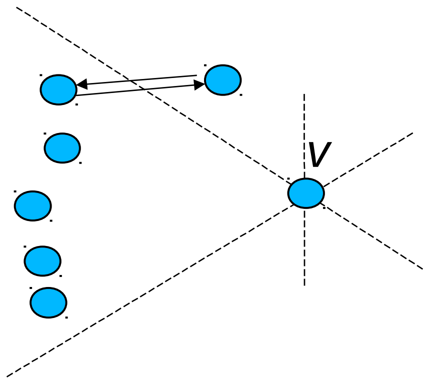


Topologies

Symmetric Yao graph (cont.)
E := { $(u,v) \in E(G_Y)$ | $(v,u) \in E(G_Y)$ }

Note:
A sector around *v* does not necesserily contain a symmetric edge!





Graph Properties

$$\text{SymmY}(V) \subseteq \text{SparsY}(V) \subseteq \text{Yao}(V)$$
$$\text{SparsY}(V) \subseteq \text{BoundY}(V).$$

Topology	Yao	BoundY	SparsY	SymmY
in-degree	n-1	$(k+1)^2$	k	k
out-degree	k	k	k	k
degree	n-1+k	$(k+1)^2+k$	2k	k

Graph Properties

Let $V \in R^2$ be a set of n nodes in the plane. Then Yao(V)

- is a c-spanner for $k > 6$ [Ruppert & Seidel 1991], where

$$c = \frac{1}{1 - 2\sin(\Theta/2)}$$

- is a c-spanner for $k = 4$ [Bose et al. 2010], where

$$c = 8\sqrt{2}(29 + 23\sqrt{2})$$

- is a weak c-spanner for $k \geq 6$ [Fischer et al. 1997], where

$$c = \max\left\{\sqrt{1 + 48\sin^4(\Theta/2)}, \sqrt{5 - \cos\Theta}\right\}$$

- is a weak c-spanner for $k = 4$ [Fischer et al. 1998] *, where

$$c = \sqrt{3 + \sqrt{5}}$$

Literature

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