Wireless Sensor Networks

18th Lecture

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CoNe Freiburg

University of Freiburg
Computer Networks and Telematics
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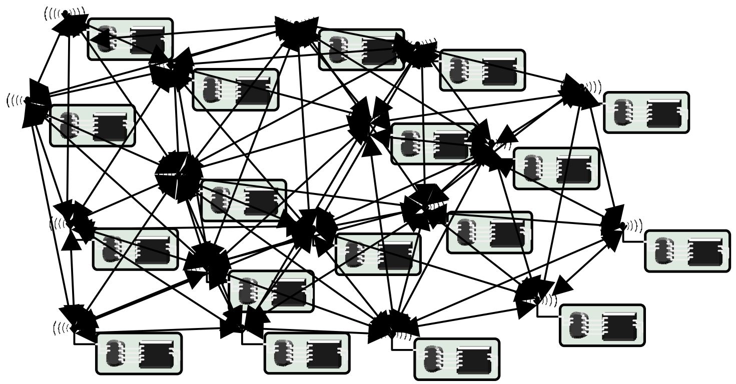
Topology Control

- **Networks can be too dense – too many nodes in close (radio) vicinity**
- **This chapter looks at methods to deal with such networks by**
  - Reducing/controlling transmission power
  - Deciding which links to use
  - Turning some nodes off

Motivation: Dense networks

- **In a very dense networks, too many nodes might be in range for an efficient operation**
  - Too many collisions/too complex operation for a MAC protocol, too many paths to chose from for a routing protocol, …



- **Idea: Make *topology* less complex**
  - ***Topology***: Which node is able/allowed to communicate with which other nodes
  - Topology control needs to maintain invariants, e.g., connectivity

Options for topology control

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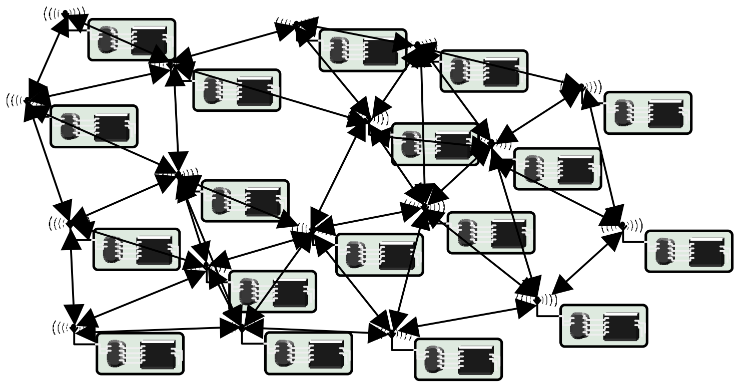
- Topology control
  - Control ***node*** activity – deliberately turn on/off nodes
  - Control ***link*** activity – deliberately use/not use certain links

- Topology control
  - ***Flat network*** – all nodes have essentially same role
    - Power control
  - ***Hierarchical network*** – assign different roles to nodes; exploit that to control node/link activity
    - Backbones
    - Clustering

Flat networks

- **Main option: Control transmission power**
  - Do not always use maximum power
  - Selectively for some links or for a node as a whole
  - Topology looks “thinner”
  - Less interference, …



- **Alternative: Selectively discard some links**
  - Usually done by introducing hierarchies

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1. Introduction
   - Definition of Geometric Spanners
   - Motivation
   - Related Work
2. Spanners versus Weak Spanners
3. Spanners versus Power Spanners
4. Weak Spanners versus Power Spanners
   - Weak Spanners are Power Spanners if Exponent > Dimension
   - Weak Spanners are Power Spanners if Exponent = Dimension
   - Weak Spanners are not always Power Spanners if Exponent < Dimension
   - Fractal Dimensions
5. Applications in Wireless Networks
6. Conclusions

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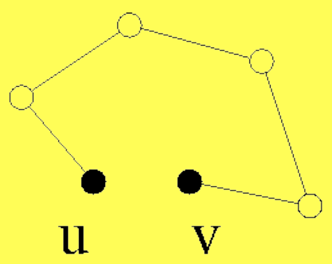
Geometric Spanner Graphs

- A Graph $G = (V, E)$ with $V \subseteq \mathbf{R}$ where for all $u, v \in V$ there exists a path $P = (u = u_1, u_2, \ldots, u_\ell = v)$ with

limited **length:**

$$||P|| := \sum_{i=2}^{\ell} |u_i - u_{i-1}|$$

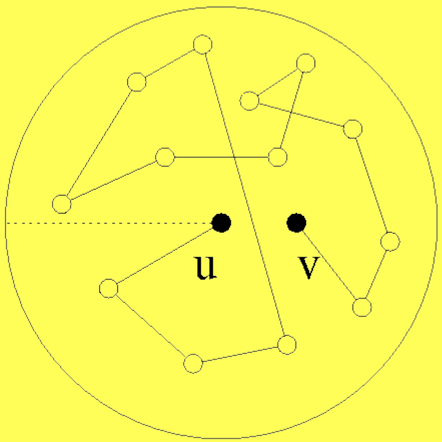
$$\leq c \cdot |u - v|$$



c-Spanner Graph

-in a limited **radius:**

$$\max_{i=1,\ldots,\ell} |u - u_i| \leq c \cdot |u - v|$$

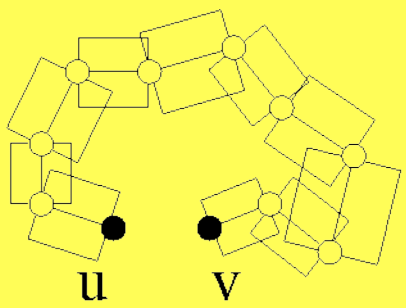


weak c-Spanner Graph

limited **energy costs:**

$$||P||^\delta := \sum_{i=2}^{\ell} |u_i - u_{i-1}|^\delta$$

$$\leq c \cdot |u - v|^\delta$$



(c,δ)-Power-Spanner Graph

Related Work for Spanner Graphs

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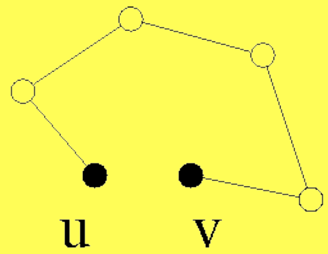
- **Spanner Graphs introduced by Chew 1986**
- **Peleg & Schaffer first use in Distributed Comptuing 1989**
- **Applications to**
  - Motion planning [Clarkson 1987]
  - Spanner Trees approximating MST [Yao 1982]
  - Used for FPAS for Traveling Salesman and related problems [Arora et al. 1998]
- **Classic survey of spanners by Eppstein [2000]**

limited **length:**

$$||P|| := \sum_{i=2}^{\ell} |u_i - u_{i-1}|$$

$$\leq c \cdot |u - v|$$



c-Spanner Graph

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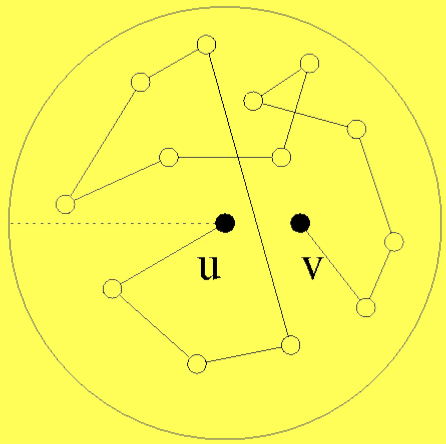
Related Work for Weak Spanners

- **Applications in geometric searching and**
- **Constructions for spanners and weak spanners with arbitrary approximation ratio (stretch factor) by**
  - Fischer, Meyer auf der Heide, Strothmann 1997
  - Fischer, Lukovszki, Ziegler 1998
- **Optimization of routing time in wireless networks**
  - Grünewald, Lukovski, S., Volbert 2002
  - Jia, Rajaraman, Scheideler 2003
- **Constructions benefitting from locality properties for ad-hoc routing networks**
  - Li, Wan, Wang 2001
  - Grünewald, Lukovski, S., Volbert 2002
  - Wang, Li 2002
  - Wang, Li, Wan, Frieder 2002

-in a limited **radius:**

$$\max_{i=1,\ldots,\ell} |u-u_i| \leq c \cdot |u-v|$$



weak c-Spanner Graph

Related Work for Power Spanners

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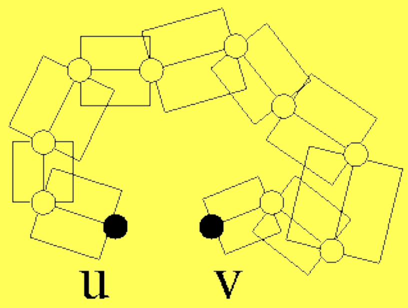
- **Power Spannners used in**
  - Grünewald, Lukovszki, S., Volbert 2002
  - Li 2003
  - Meyer auf der Heide, S, Volbert, Grünewald, 2004
- **Special cases:**
  - $\delta = 0$: Hop Spanners,
    - used by Alzoubi et al. 2003
  - $\delta = 1$: Power Spanner = Spanner
  - $\delta = 2$: Usual Power Spanner
    - (ad hoc networking)
  - $\delta > 2$: Energy consumption for messages in reality
    - Rappaport 1996 chooses δ up to 8

limited **energy costs:**

$$||P||^\delta := \sum_{i=2}^{\ell} |u_i - u_{i-1}|^\delta$$

$$\leq c \cdot |u - v|^\delta$$



(c,δ)-Power-Spanner Graph

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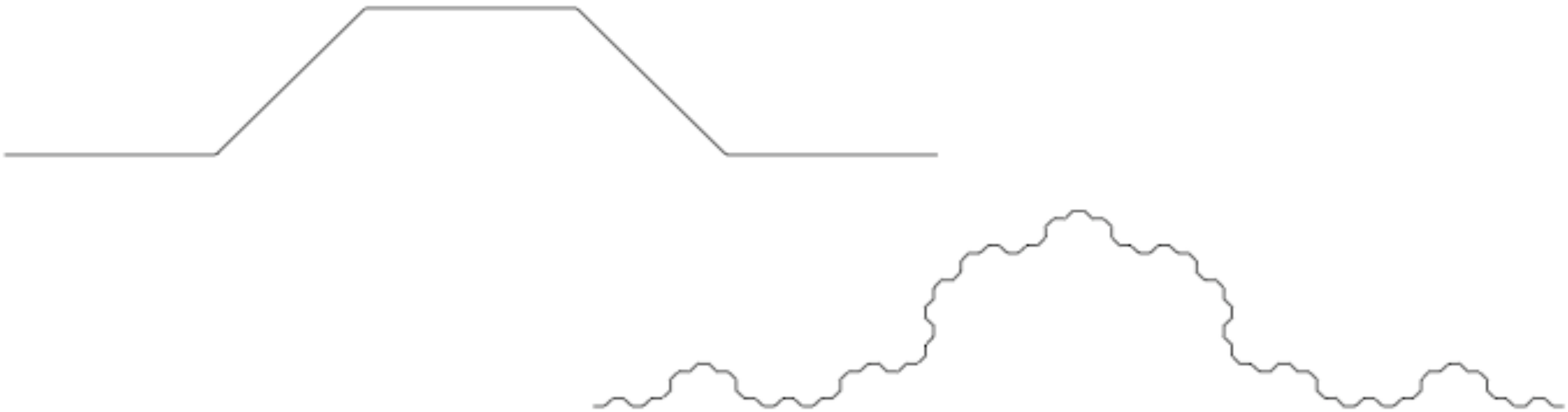
Spanners versus Weak Spanners

- **Fact**
  - **Every c-Spanner is also a c-Weak Spanner**
- **Theorem**
  - **There are Weak Spanner which are no Spanners**
- **Proof Idea [Eppstein]: use fractal construction**



Thank you

(and thanks go also to ***Holger Karl*** *for providing some slides)*

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