Wireless Networks Models

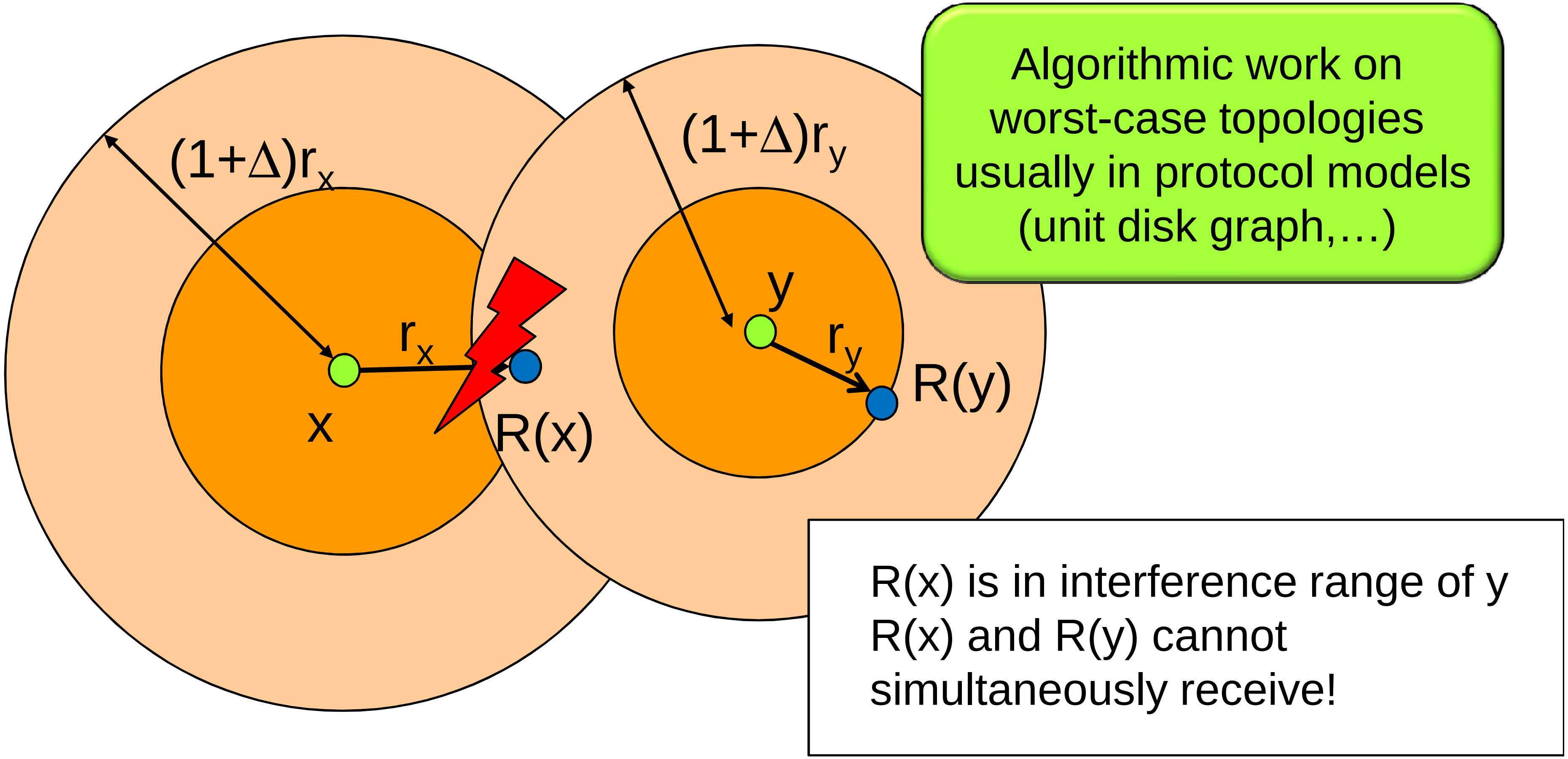
Models

- Two standard models in wireless networking

Protocol Model (graph-based, simpler) ⟷ Physical Model (SINR-based, more realistic)

Protocol Model

- Based on graph-based notion of interference
- Transmission range and interference range



Models

Algorithmic models often inspired by
- "Connections" => Graph Theory
- Transmission ranges, interference, … => Geometry

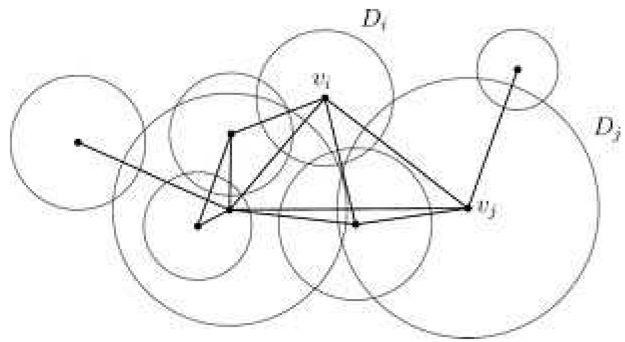
"Higher level abstractions"

Connectivity: Disk Graph

Which nodes are adjacent to a given node *v*?

Disk Graph (DG)

- Each node has a communication range
- $\{u,v\} \in E \Leftrightarrow |u,v| < \text{Range}$

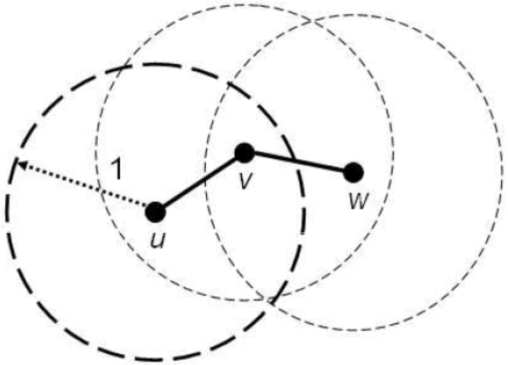


Connectivity: Unit Disk Graph

Which nodes are adjacent to a given node *v*?

Example: Unit Disk Graph (UDG)

- Classic Model from computational ge
- $\{u,v\} \in E \Leftrightarrow |u,v|\ \ 1$



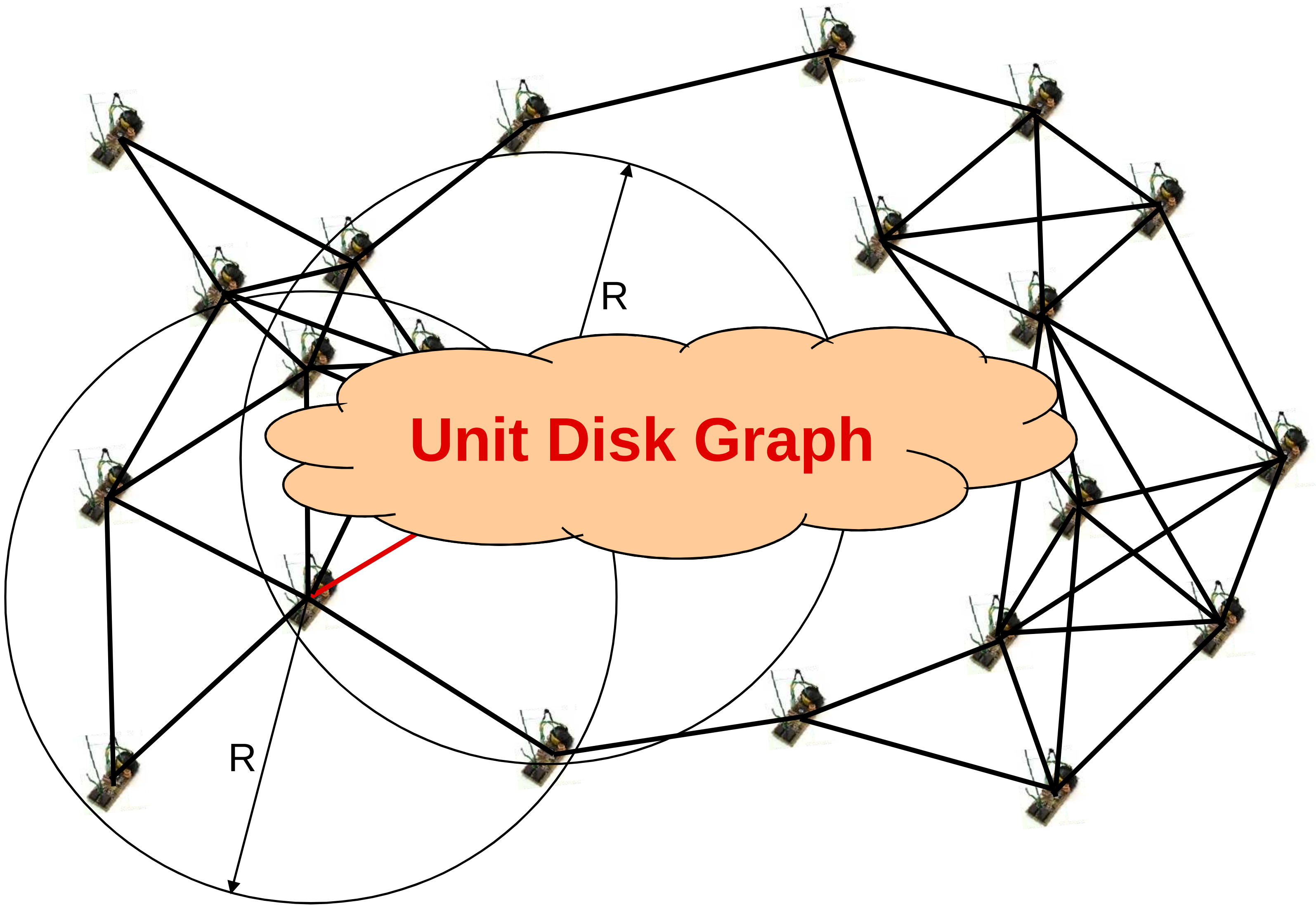
Pro

- Very simple
- Analytically tractable
- Realistic for unobstructed environments

Contra

- Too simple
- Not realistic for inner-city networks with many buildings etc.

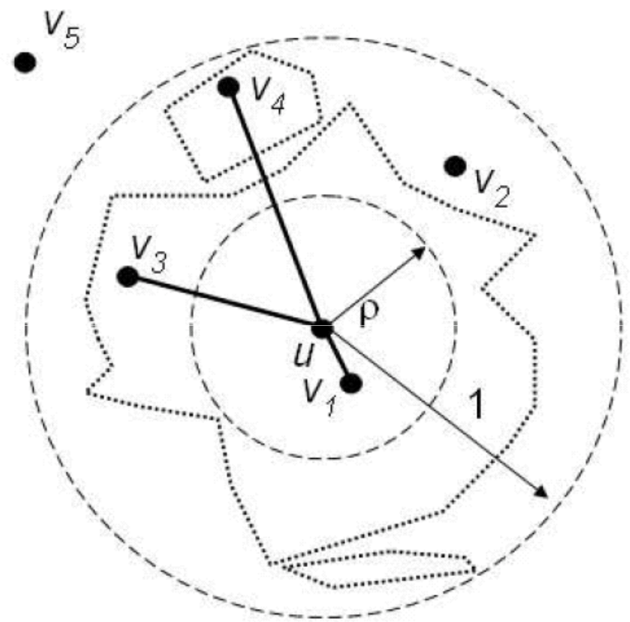
Connectivity: Unit Disk Graph



Connectivity: Quasi Unit Disk Graph

More realistic: *Quasi* UDG (QUDG)

- two radii
- $\{u,v\} \in E \Leftrightarrow |u,v|\ \ \rho$
- $\{u,v\}| \in E \Leftrightarrow |u,v| > 1$
- otherwise: It depends!



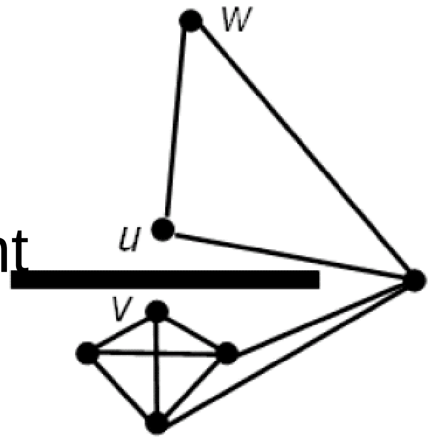
It depends…

- … on an adversary,
- … on probabilistic model,
- etc.!

Advantage: More flexible and realistic than UDG!

Connectivity: Drawbacks of QUDG

How realistic is QUDG?
- if there is a wall…
- … *u* and *v* can be close but not adjacent
- => QUDG model requires very small ρ



However, although if there are walls, connectivity typically still adheres to certain geometric constraints!
- Resort to general connectivity graphs too pessimistic!

Observation: Even in complex environments, the neighbors of a node are often also neighboring (cf wall example)
- Motivation for Bounded Independence Graph!

Physical Model

- Based on signal-to-noise-plus-interference (SINR)
- Simplest case:

  → packets can be decoded if SINR is larger than β at receiver

Received signal power from sender

Power level of sender u

Path-loss exponent

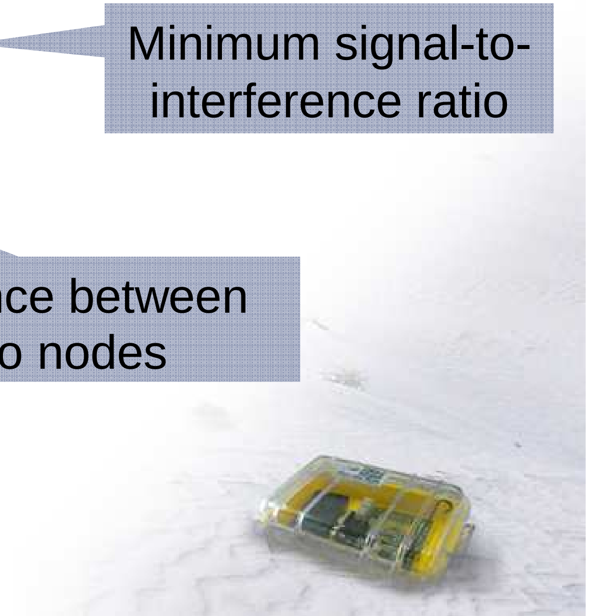
$$\frac{\frac{P_u}{d(u,v)^{\alpha}}}{N + \sum_{w \in V \setminus \{u\}} \frac{P_w}{d(w,v)^{\alpha}}} \geq \beta$$

Minimum signal-to-interference ratio

Noise

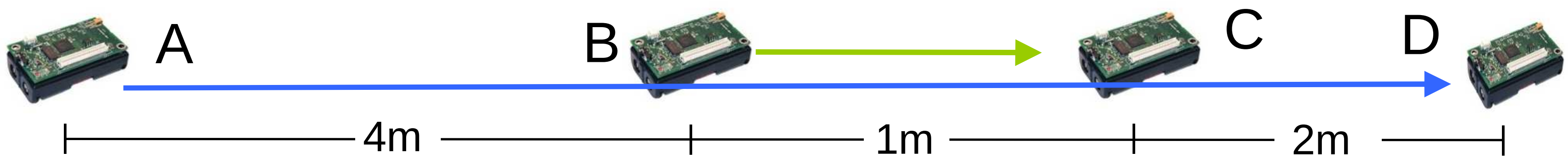
Received signal power from all other nodes (=interference)

Distance between two nodes



Example: Protocol vs. Physical Model

A sends to D, B sends to C



Assume a single frequency (and no fancy decoding techniques!)

Is spatial reuse possible?

- NO — Protocol Model
- YES — Physical Model
- YES — In Reality!

Let α=3, β=3, and N=10nW

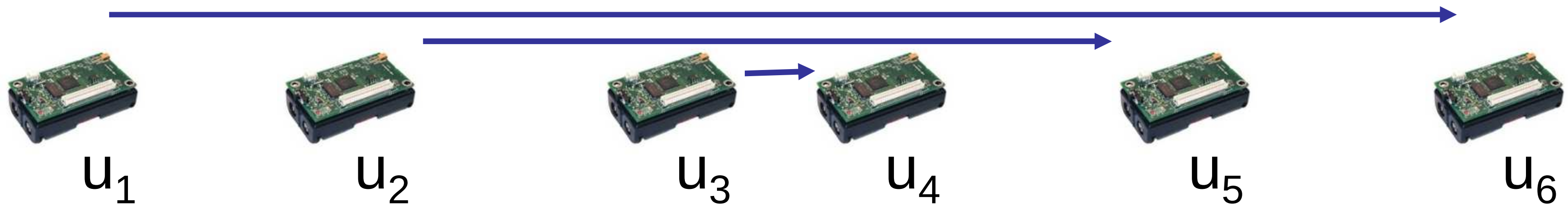
Transmission powers: P_B= -15 dBm and P_A= 1 dBm

SINR of A at D: $$\frac{1.26mW/(7m)^3}{0.01\mu W+31.6\mu W/(3m)^3} \approx 3.11 \geq \beta$$

SINR of B at C: $$\frac{31.6\mu W/(1m)^3}{0.01\mu W+1.26mW/(5m)^3} \approx 3.13 \geq \beta$$

Real work in practice!

- Measurements using standard mica2 nodes!
- Replaced standard MAC protocol by a (tailor-made) „SINR-MAC“
- Measured for instance the following deployment...



- Time for successfully transmitting 20‘000 packets:

	Time required	
	standard MAC	“SINR-MAC”
Node u_1	$721s$	$267s$
Node u_2	$778s$	$268s$
Node u_3	$780s$	$270s$

	Messages received	
	standard MAC	“SINR-MAC”
Node u_4	19999	19773
Node u_5	18784	18488
Node u_6	16519	19498

Speed-up is almost a factor 3

[Moscibroda, Wattenhofer, Weber, Hotnets’06]