

INTRODUCTION TO WIRELESS SENSOR NETWORKS

CHAPTER 4: LINK MANAGEMENT

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OVERVIEW

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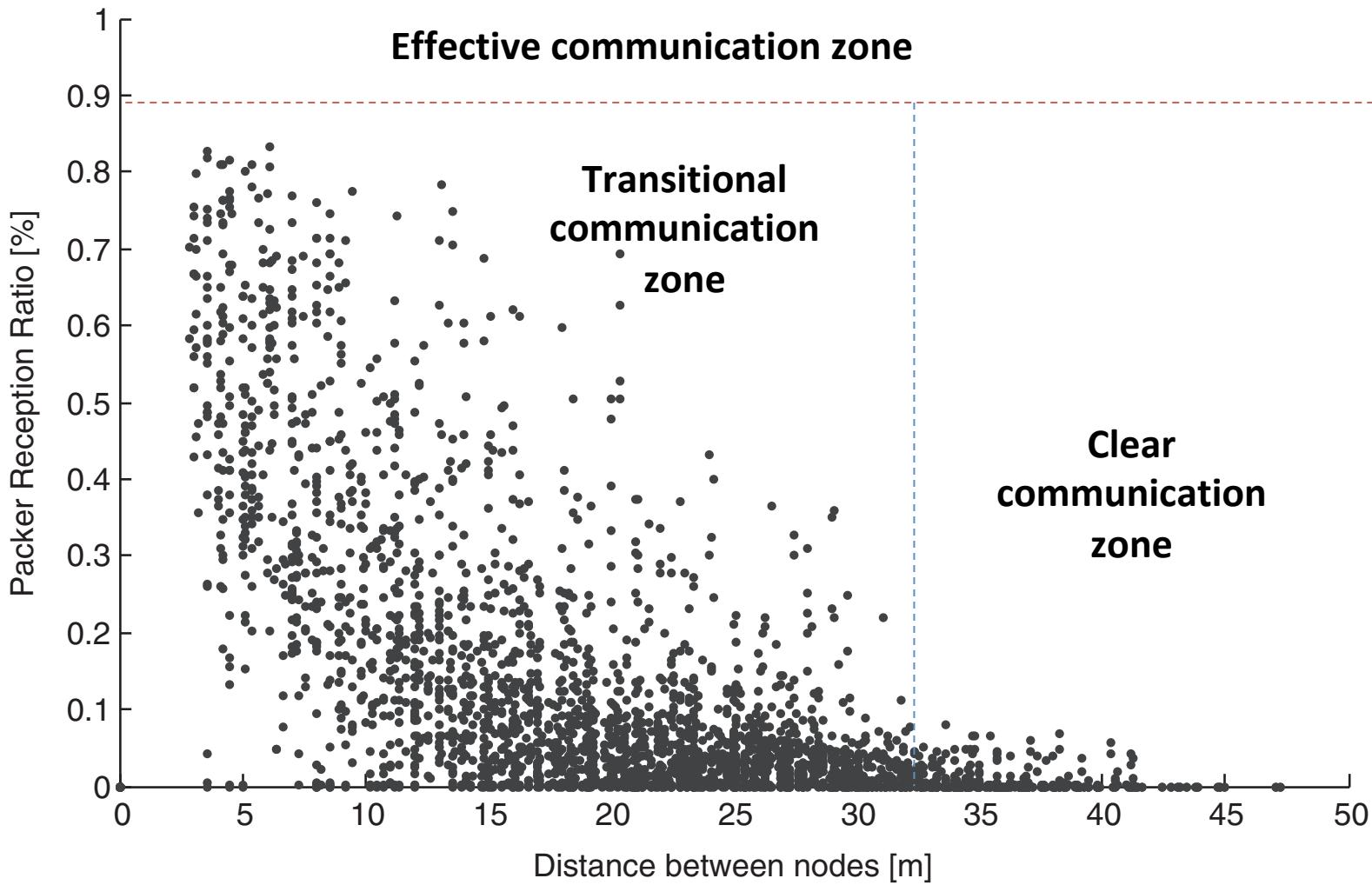
Introduction

A wireless link is unreliable, not symmetric, and highly fluctuates in time and space.

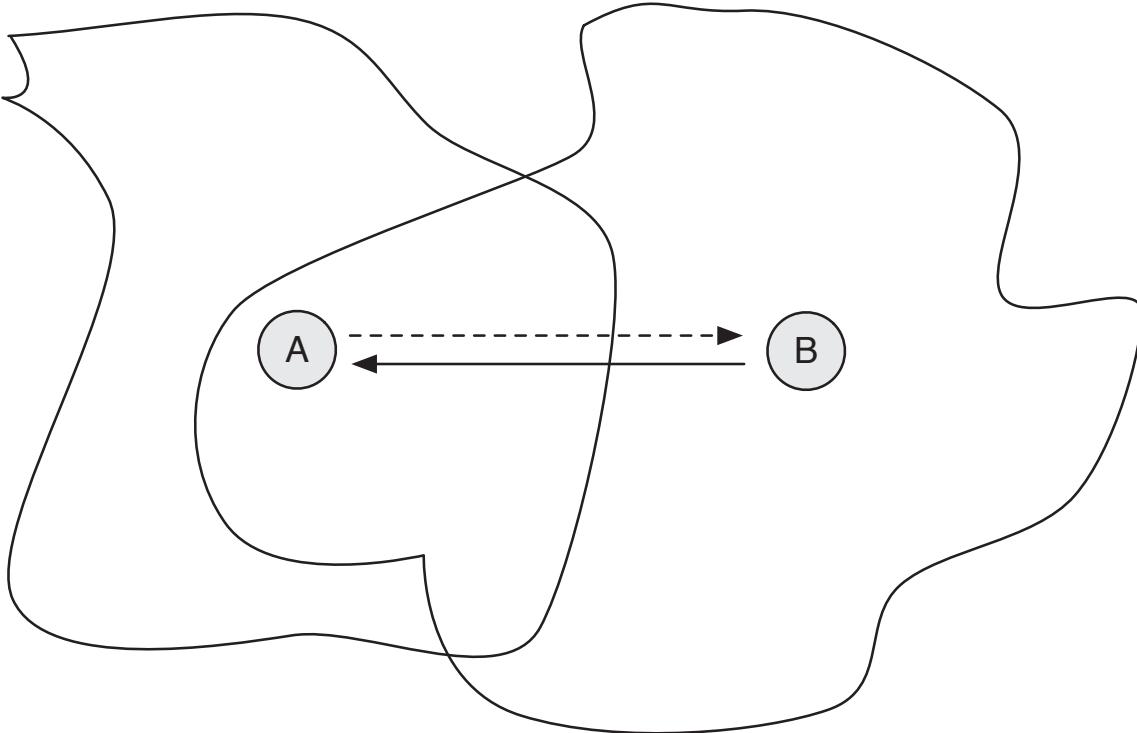
Metrics for estimating quality of links:

- Packet Reception Ratio (PRR)
- Received Signal Strength Indicator (RSSI)
- Link Quality Indicator (LQI)
- Signal to Noise Ratio (SNR)

Links and Geographic Distance

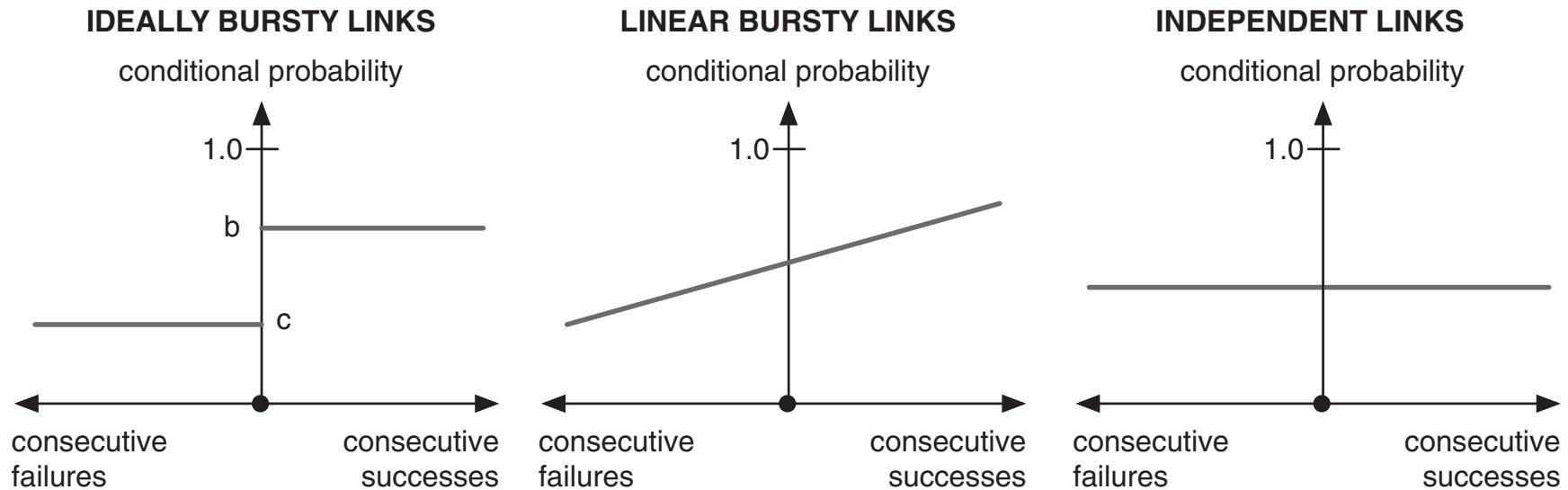


Asymmetric Links



Burstiness of Links

- Measured with ***Conditional Probability Delivery Function*** (CPDF)



Error Control

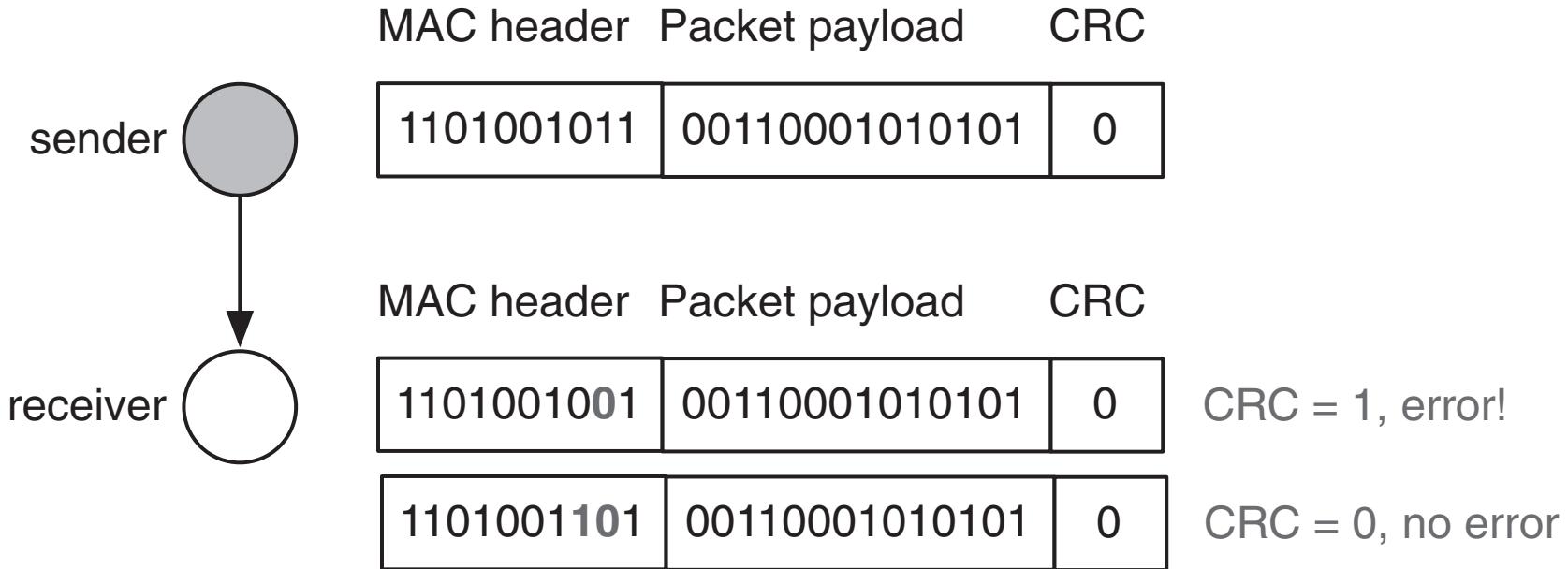
Guarantee communication to be:

- Error-free
- Loss-free
- (In-sequence)
- (Duplicate-free)

Backward Error Control

Wait for the errors to happen and repair the problem:

- Checksum or Cyclic Redundancy Checksum (CRC)
- Automatic Repeat Request or Retransmit

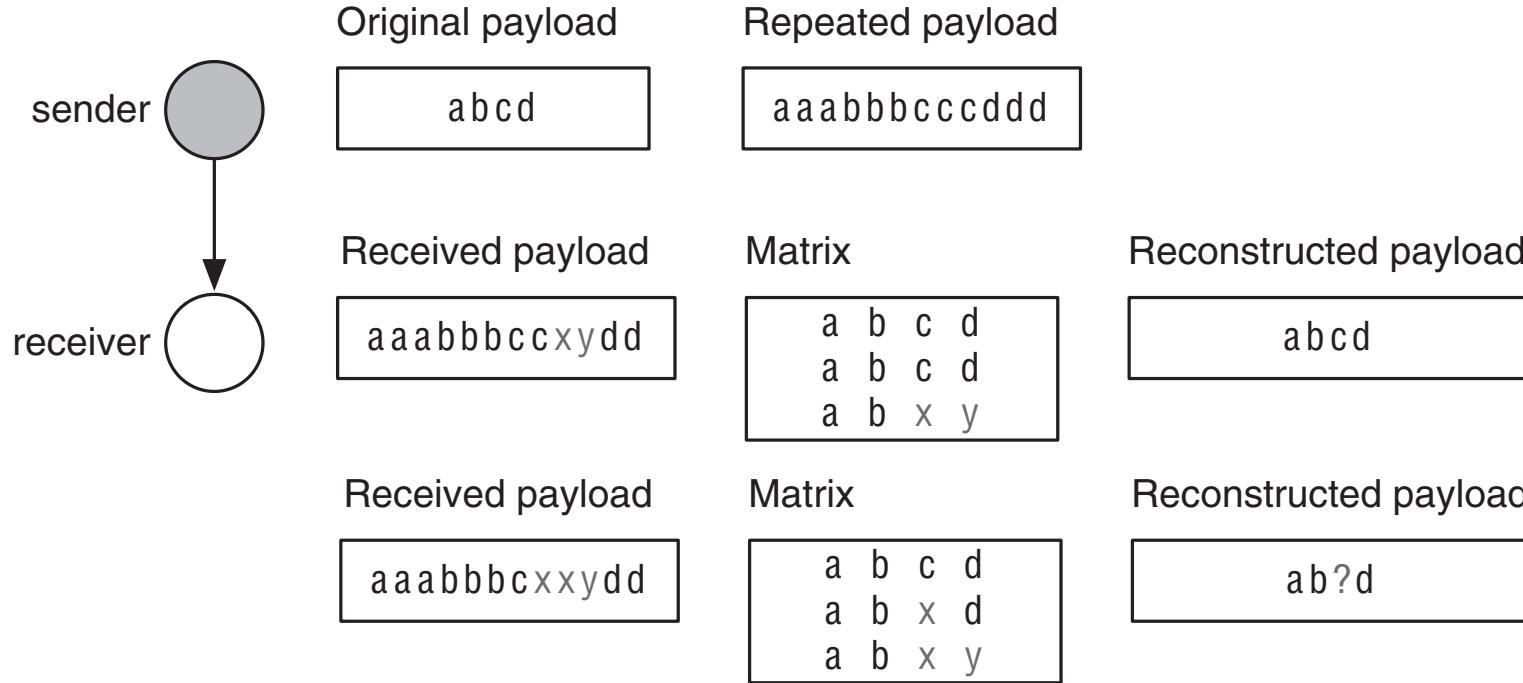


Forward Error Control (FEC)

Sending a new packet is very costly and uses not only energy, but also precious bandwidth. Sending a couple of more bits or bytes into a packet, which needs to get out anyway, is almost without cost.

Forward Error Control (FEC)

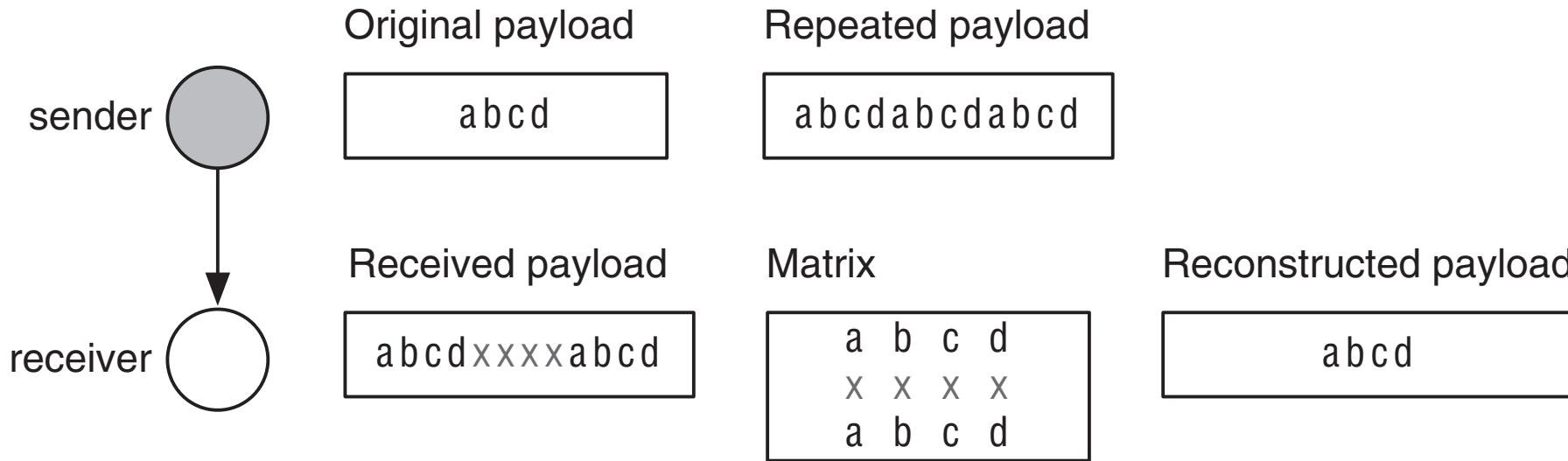
Repeating Code



Problem: clustered errors

Forward Error Control (FEC)

Interleaving Code



Naming

- Abstract Identification of Nodes
 - A, B, C, etc.
 - Mac Addresses of Devices
- Role or data identification
 - Washing Machine 1, Heating in the Living Room
 - Temperature, humidity, light
- Names can be unique or not

Addressing

- Reveals the position of the node
 - In the network
 - In the geographic world
- Example: IP addresses

Name and Address Assignment

- **Size and length:** make sure you have enough addresses or names!
- **Storage:** store in volatile or persistent memory
- **Positioning and Repositioning:** change the name/address if the node moves or changes its role
- **Uniqueness:** it is more practical to have unique names and addresses

Link Estimation Protocols

- Protocol which gathers link quality information about neighbors
- Marks the neighbors as “good”, “average” and “bad”
- Same as Neighborhood Management Protocol
- Design criteria:
 - Precision
 - Agility
 - Stability
 - Efficiency

Link Quality Based

- Use RSSI or LQI (or similar or combinations thereof)
- Example: all links with $\text{RSSI} > -60$ are considered very good links
- Discussion of properties:
 - Precision: not good
 - Agility: rather good
 - Stability: not good
 - Efficiency: good for memory/communication overhead, average for processing needs

Delivery Rate Based

- Send many packets to all neighbors and estimate directly the delivery rate
- Discussion of properties:
 - Precision: quite good
 - Agility: not good, depends on recalculation window
 - Stability: good, opposite to agility, depends on recalculation window
 - Efficiency: not good for memory/communication overhead, good for processing needs

Passive and Active Estimators

- Passive Snooping: Observe existing packets only
 - Very efficient
 - Not very precise or agile
- Active Sending: Produce additional packets and observe their properties
 - Very agile and precise
 - Not efficient
- Usually protocols are combination thereof

Collection Tree Protocol (CTP)

- CTP consists of a link estimator and a routing part.
- Uses ETX: A network-wide metric, which computes how many hops on average a node needs to reach the sink
- Defines a sending interval σ_{low} to balance passive snooping and active sending
- Another interval σ_{low} is used to register changes in the network
- Explores each neighbor in terms of its ETX to the sink
- Sends regularly packets with own ETX to sink to all neighbors

Topology Control

- The topology (the neighborhood, the “visible” neighbors” can be controlled:
 - Directly by changing the transmission power (saves energy)
 - Indirectly by ignoring some neighbors with low quality (not often used)
- Main Challenges:
 - Asymmetric Links
 - Directional Links
 - Discovery of neighbors

Centralized Topology Control

- Gather all information about all nodes at the sink
- Compute the optimal / desired topology and the corresponding parameters
- Send the parameters to all nodes
- Discussion:
 - Very complex to obtain all data (link quality at different transmission powers)
 - Not agile

Distributed Topology Control

- Each node tries out different transmission power
- Each node observes the link quality to neighbors and decides on its own
- Discussion:
 - More flexible and situation-aware
 - Very complex and might never stabilize

Link Management: Summary

- Quality is not linear with geographic distance.
- Asymmetry exists, where quality is different in both directions.
- Wireless links are bursty, i.e., bit errors occur not independently.

Link management involves several tasks:

- **Error control** differentiates between *forward error control* and *backward error control*.
- You assign unique **names** to individual nodes, which refer to their role or properties, and **addresses**, which refer to their positions.
- **Link estimation** refers to maintaining quality indicators for individual neighbors. It can be delivery rate based or link quality based. Link estimation can be *passive* (overhear existing communication only) and *active* (creating its own communication). CTP uses a delivery rate based link estimator. Link estimation has to fulfill the following properties: *precision*, *agility*, *stability*, and *efficiency*.
- **Topology control** plays with the transmission power of individual nodes to change their communication neighbors. It can be designed to be *centralized* (one node decides about the transmission power of all) or *distributed* (each node decides on its own).