

INTRODUCTION TO WIRELESS SENSOR NETWORKS

CHAPTER 4: LINK MANAGEMENT

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OVERVIEW

1. Introduction
2. Properties of Wireless Links
3. Error Control
4. Naming and Addressing
5. Link Estimation Protocols
 1. Link Quality Based
 2. Delivery Rate Based
 3. Passive and Active Estimators
6. Topology Control
 1. Centralized
 2. Distributed

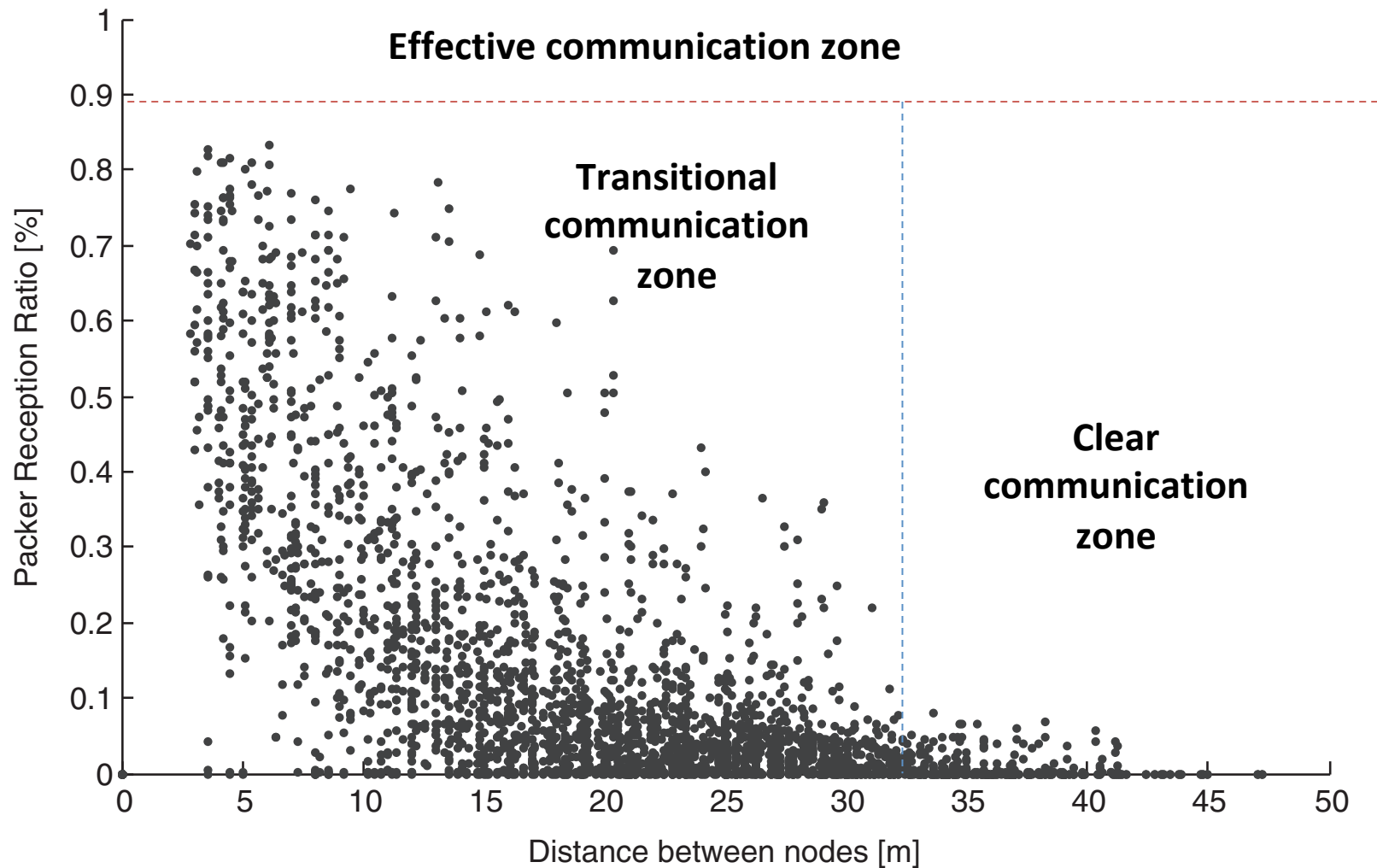
Introduction

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

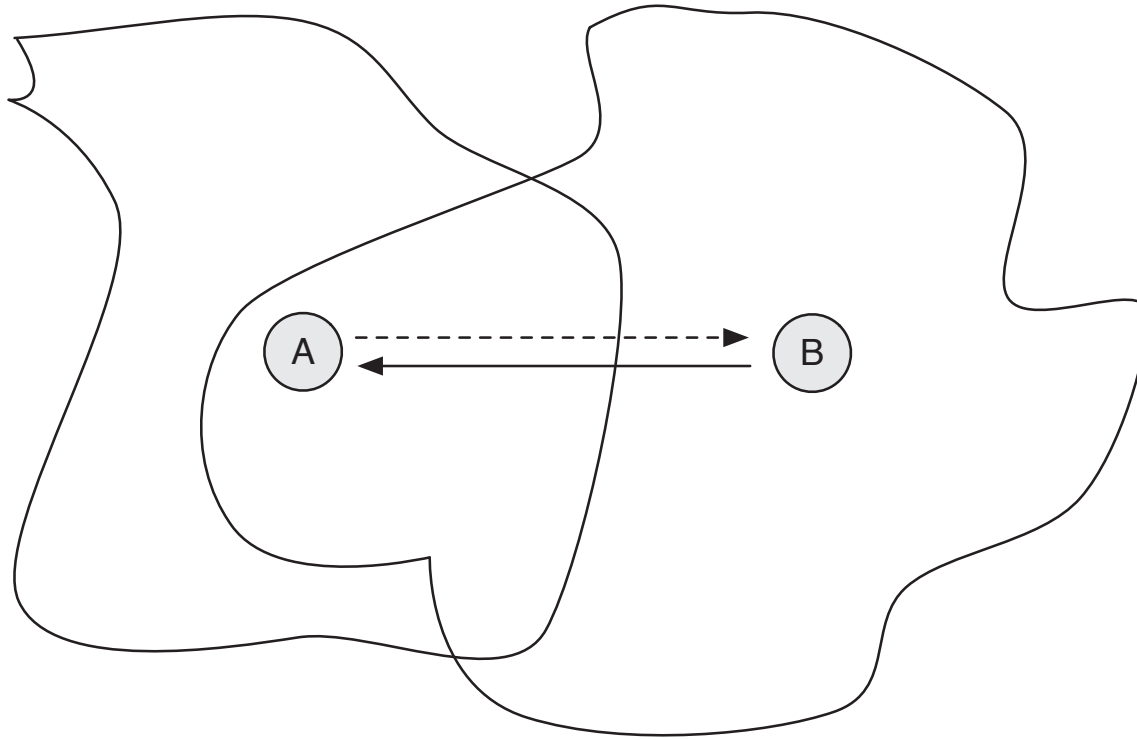
Metrics for estimating quality of links:

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

Links and Geographic Distance

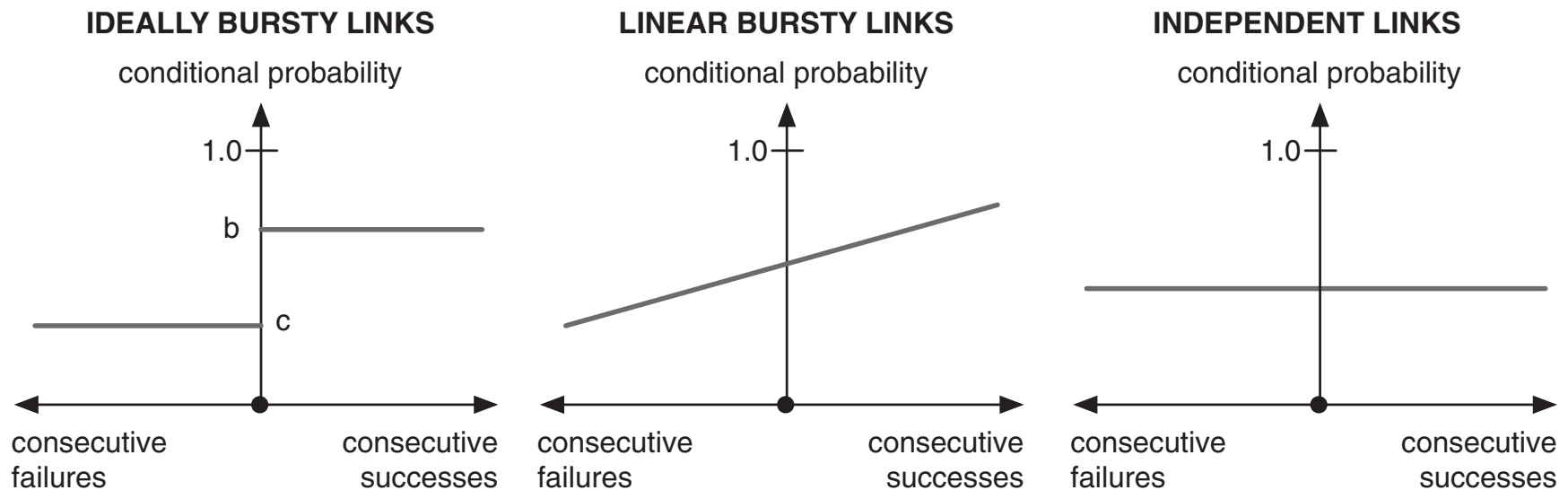


Asymmetric Links



Burstiness of Links

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



Error Control

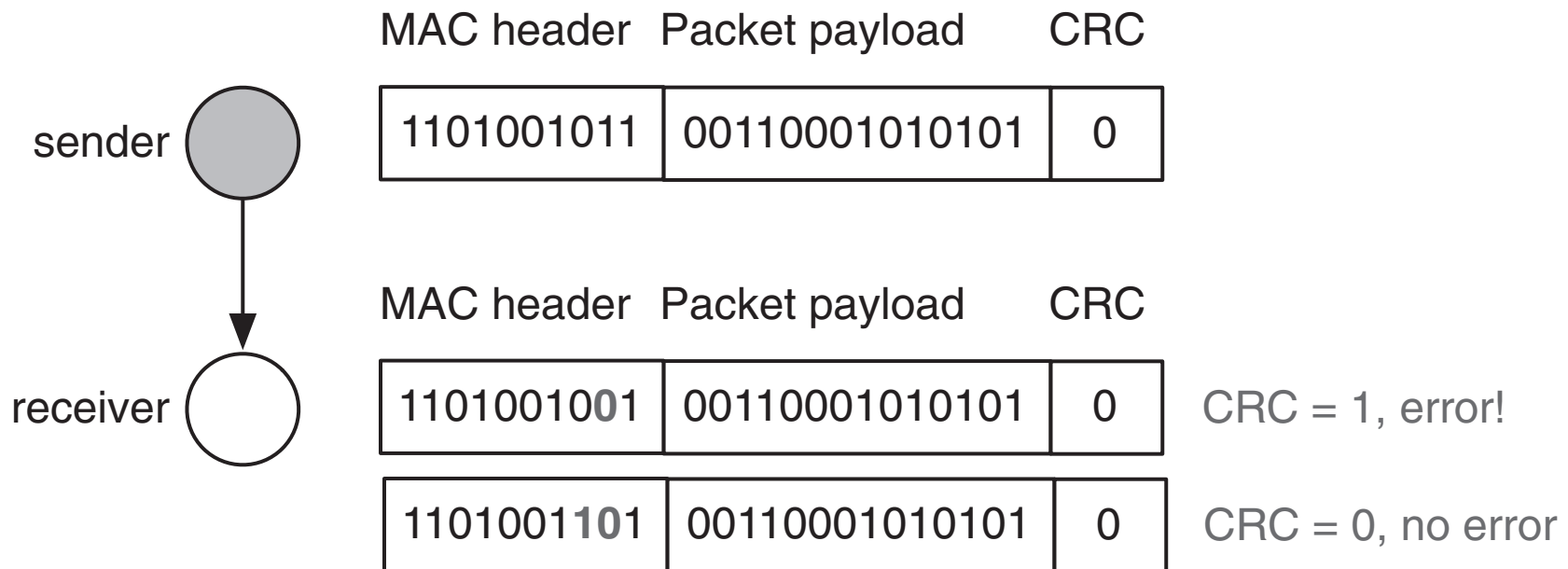
Guarantee communication to be:

- 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

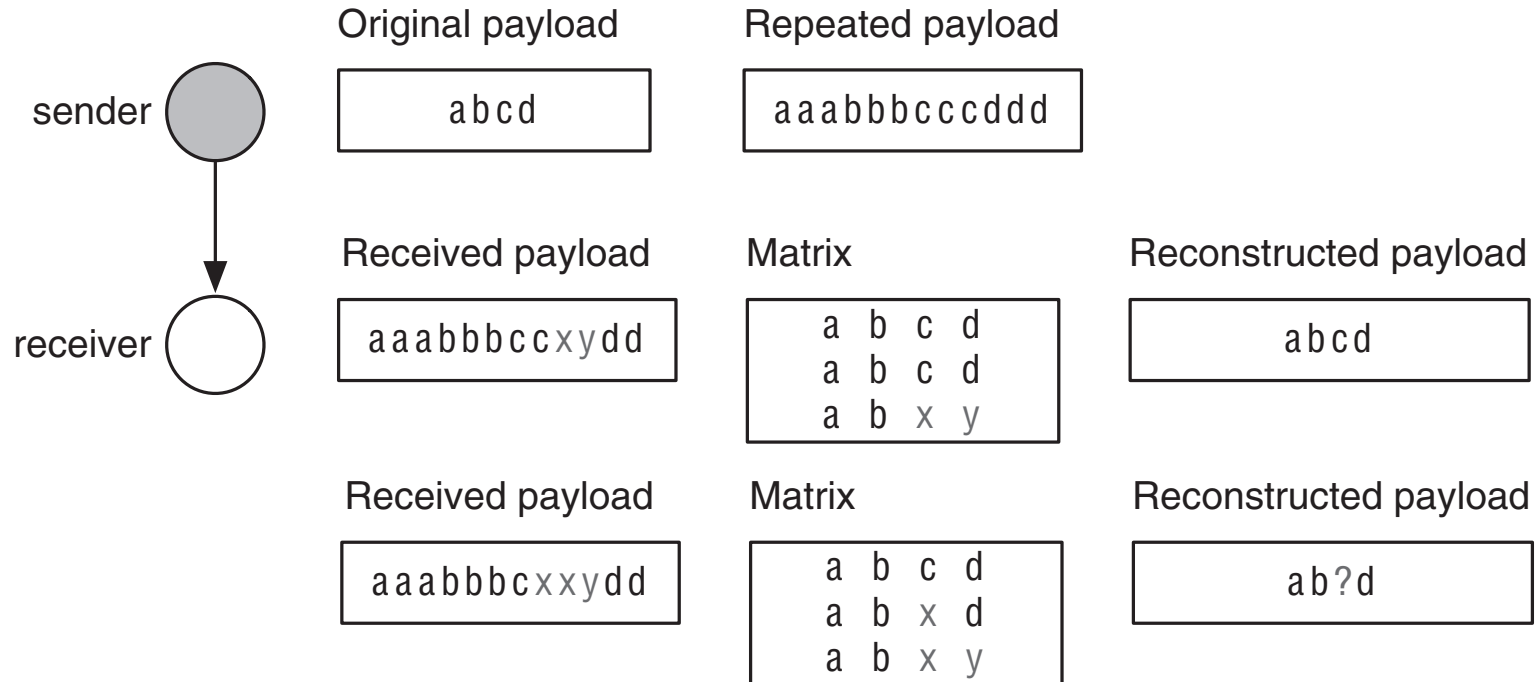


Forward Error Control (FEC)

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)

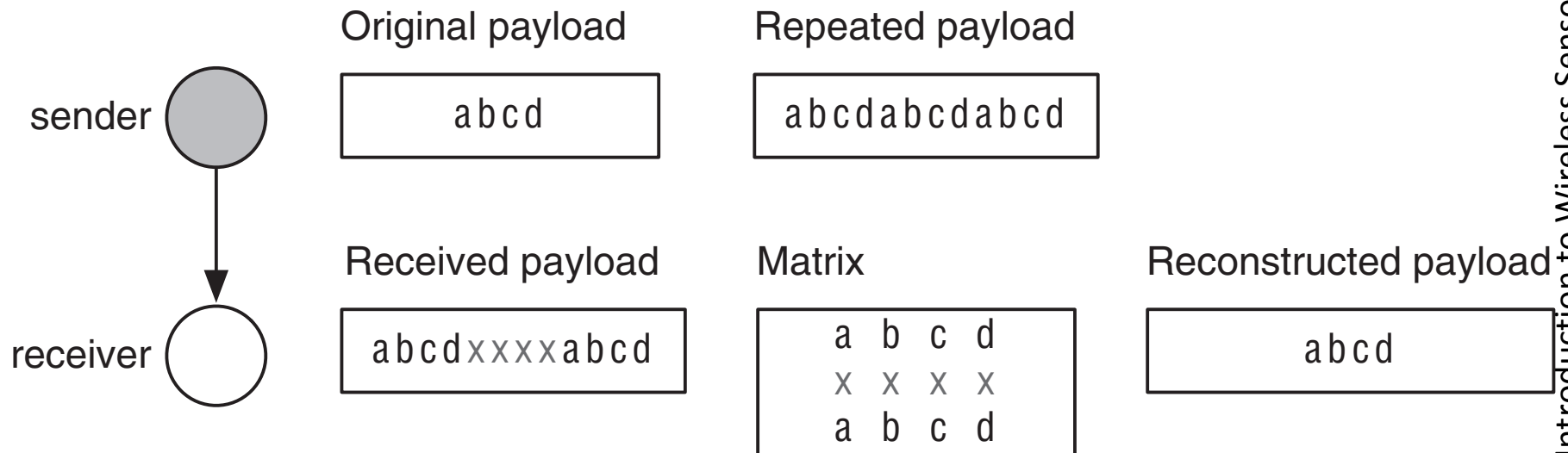
Repeating Code



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).