EEEN3008J: Advance wireless communications

Wireless communications

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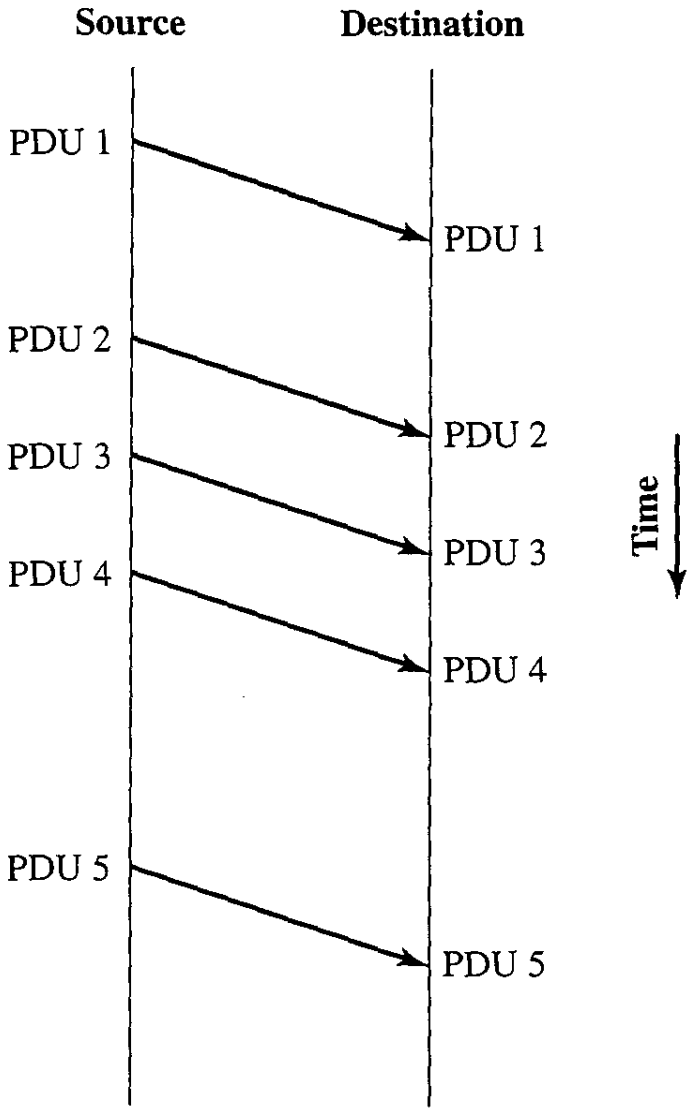
Automatic Repeat Request (ARQ)

Automatic Repeat Request

- Mechanism used in data link control and transport protocols
- Relies on use of an error detection code (such as CRC)
- Flow Control
- Error Control

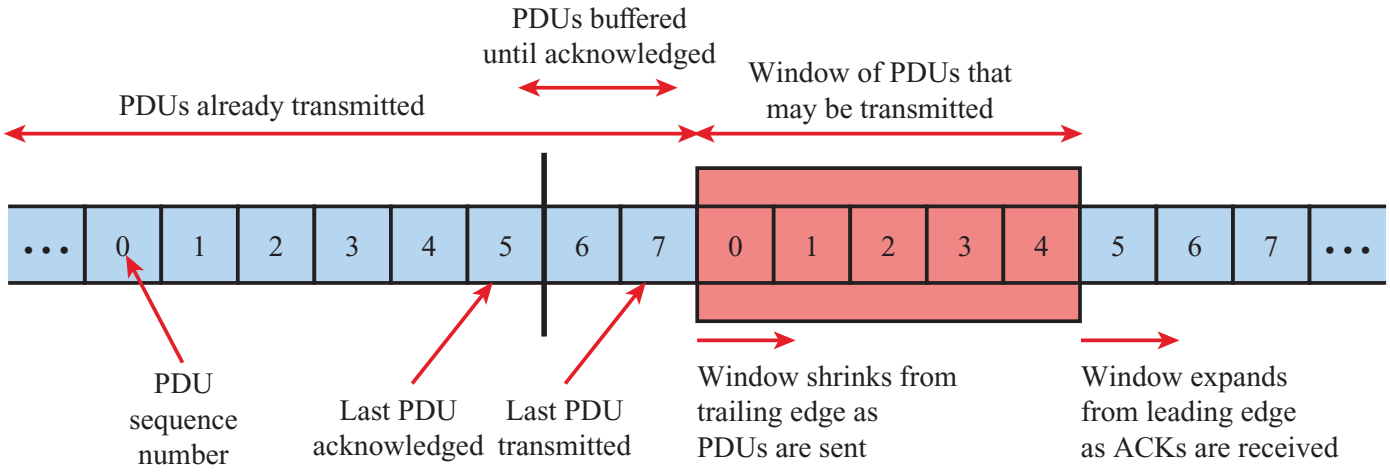
Model of Error-Free PDU Transmission



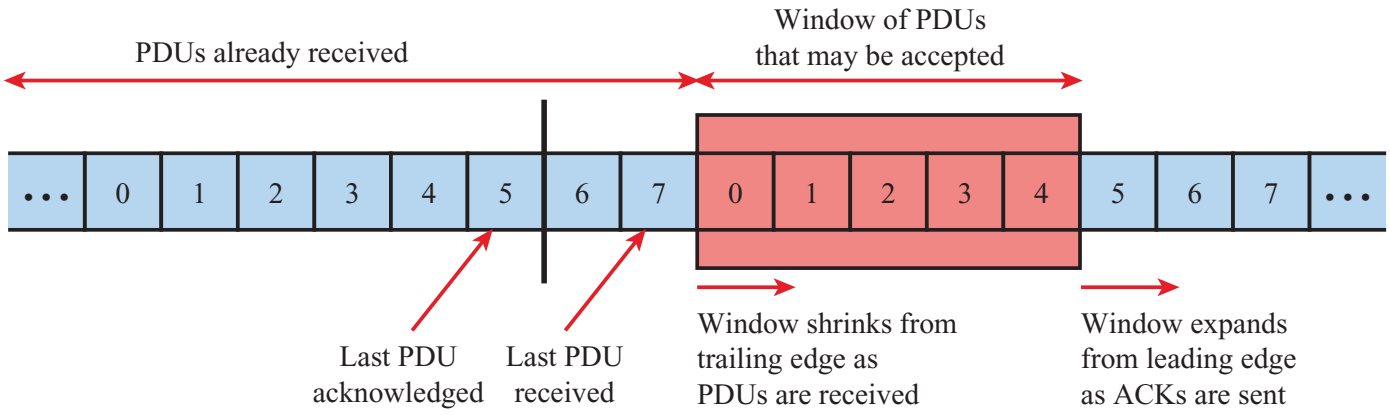
Flow Control

- Assures that transmitting entity does not overwhelm a receiving entity with data
- Protocols with flow control mechanism allow multiple PDUs in transit at the same time
- PDUs arrive in same order they are sent
- Sliding-window flow control
  - Transmitter maintains list (window) of sequence numbers allowed to send
  - Receiver maintains list allowed to receive

Sliding Window Depiction



(a) Sender's perspective



(b) Receiver's perspective

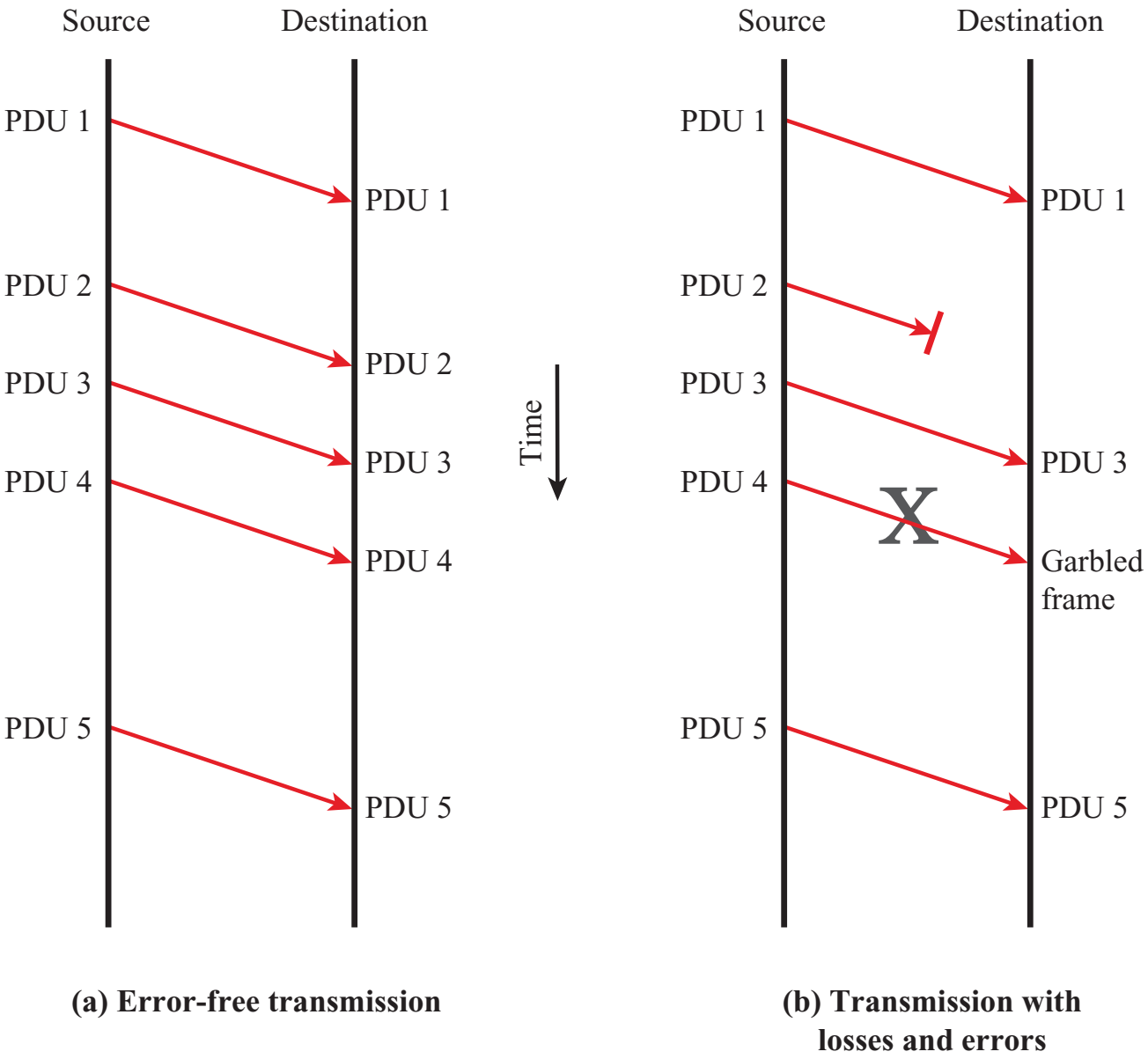
Example of a Sliding Window Protocol

Flow Control

- Reasons for breaking up a block of data before transmitting:
  - Limited buffer size of receiver
  - Retransmission of PDU due to error requires smaller amounts of data to be retransmitted
  - On shared medium, larger PDUs occupy medium for extended period, causing delays at other sending stations

Error Control

- Mechanisms to detect and correct transmission errors
- Types of errors:
  - Lost PDU : a PDU fails to arrive
  - Damaged PDU : PDU arrives with errors



Model of PDU Transmission

Error Control Requirements

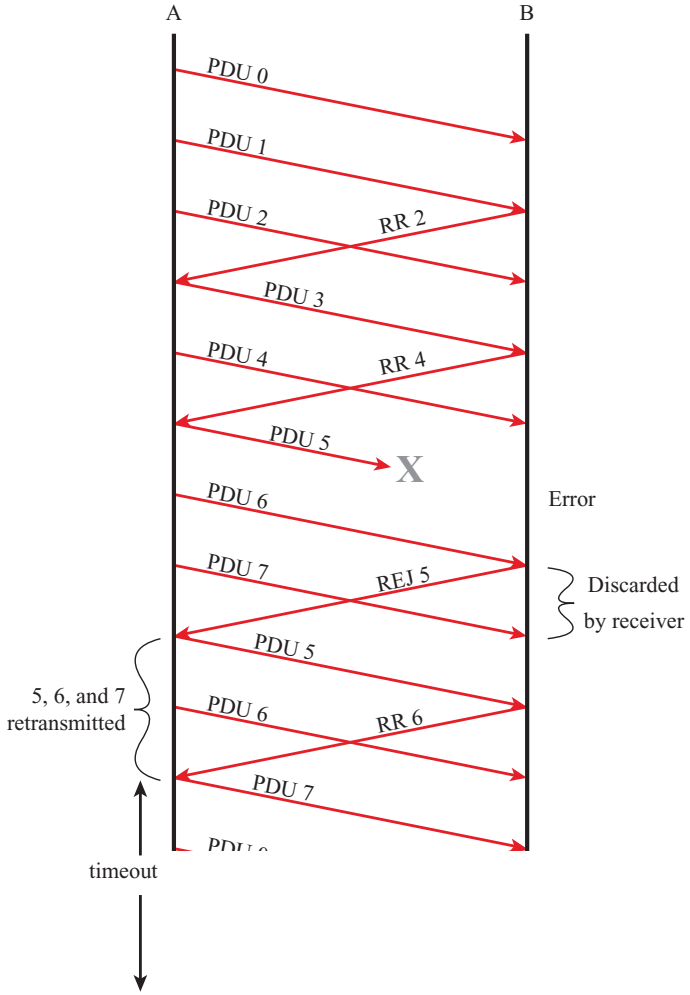
- Error detection
  - Receiver detects errors and discards PDUs
- Positive acknowledgement
  - Destination returns acknowledgment of received, error-free PDUs
- Retransmission after timeout
  - Source retransmits unacknowledged PDU
- Negative acknowledgement and retransmission
  - Destination returns negative acknowledgment to PDUs in error

Go-back-N ARQ

- Acknowledgments
  - RR = receive ready (no errors occur)
  - REJ = reject (error detected)
- Contingencies
  - Damaged PDU
  - Damaged RR
  - Damaged REJ

Go-back-N ARQ: Contingencies

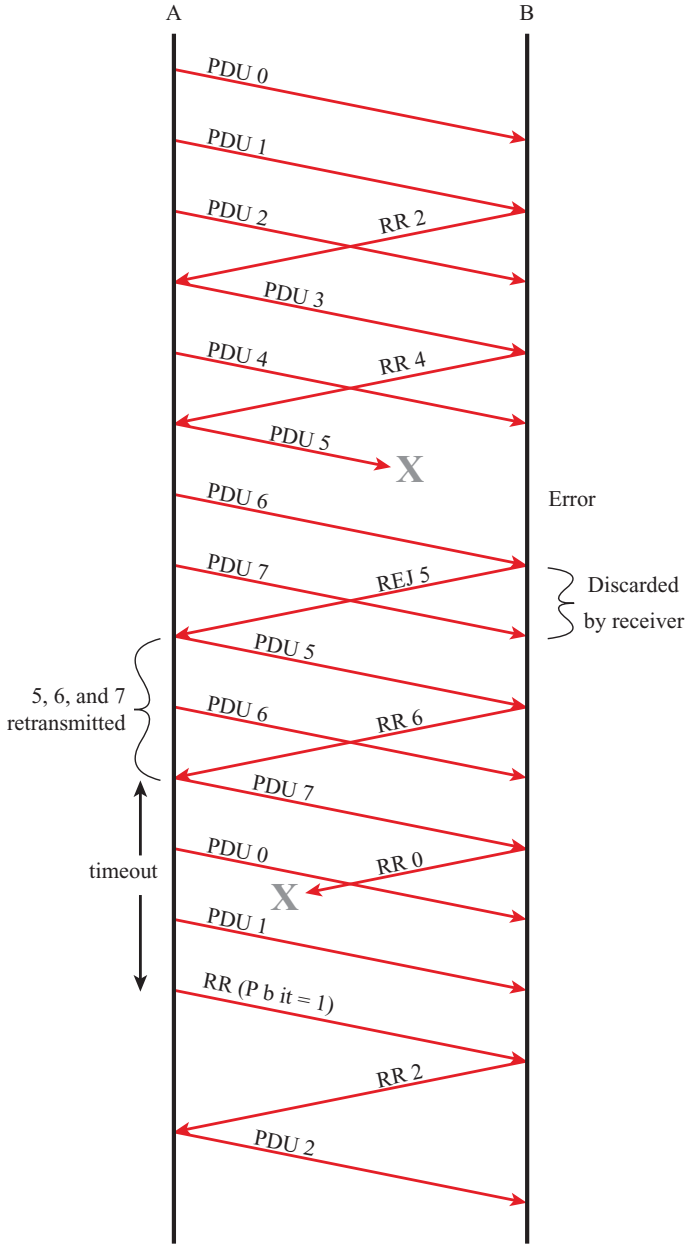
- **1. Damaged PDU:** If the received PDU is invalid (i.e., B detects an error), B discards the PDU and takes no further action as the result of that PDU. There are two subcases:
  - (a) Within a reasonable period of time, A subsequently sends PDU *(i* + 1). B receives PDU *(i* + 1) out of order and sends a REJ *i.* A must retransmit PDU *i* and all subsequent PDUs.
  - (b) A does not soon send additional PDUs. B receives nothing and returns neither an RR nor a REJ. When A's timer expires, it transmits an RR PDU that includes a bit known as the P bit, which is set to 1. B interprets the RR PDU with a P bit of 1 as a command that must be acknowledged by sending an RR indicating the next PDU that it expects, which is PDU *i.* When A receives the RR, it retransmits PDU *i.*


A
B
PDU 0
PDU 1
PDU 2
RR 2
PDU 3
PDU 4
RR 4
PDU 5
X
Error
PDU 6
PDU 7
REJ 5
Discarded
by receiver
PDU 5
5, 6, and 7
retransmitted
PDU 6
RR 6
PDU 7
timeout

Go-back-N ARQ

Go-back-N ARQ: Contingencies

- **2. Damaged RR.** There are two subcases:
  - (a) B receives PDU *i* and sends RR *(i* + 1), which suffers an error in transit. Because acknowledgments are cumulative (e.g., RR 6 means that all PDUs through 5 are acknowledged), it may be that A will receive a subsequent RR to a subsequent PDU and that it will arrive before the timer associated with PDU *i* expires.
  - (b) If A's timer expires, it transmits an RR command as in Case lb. It sets another timer, called the P-bit timer. If B fails to respond to the RR command, or if its response suffers an error in transit, then A's P-bit timer will expire. At this point, A will try again by issuing a new RR command and restarting the P-bit timer. This procedure is tried for a number of iterations. If A fails to obtain an acknowledgment after some maximum number of attempts, it initiates a reset procedure.
- **3. Damaged REJ.** If a REJ is lost, this is equivalent to Case lb.


A
B
PDU 0
PDU 1
PDU 2
RR 2
PDU 3
PDU 4
RR 4
PDU 5
X
Error
PDU 6
PDU 7
REJ 5
Discarded
by receiver
PDU 5
5, 6, and 7
retransmitted
PDU 6
RR 6
PDU 7
PDU 0
RR 0
timeout
X
PDU 1
RR (P b it = 1)
RR 2
PDU 2

Go-back-N ARQ

HYBRID ARQ

- Hybrid Automatic Repeat Request (HARQ)
  - Neither FEC or ARQ is adequate in practical situations
    - FEC may add unnecessary redundancy
    - ARQ may cause excessive delays from retransmissions
  - HARQ is widely used
  - Uses combination of FEC and ARQ

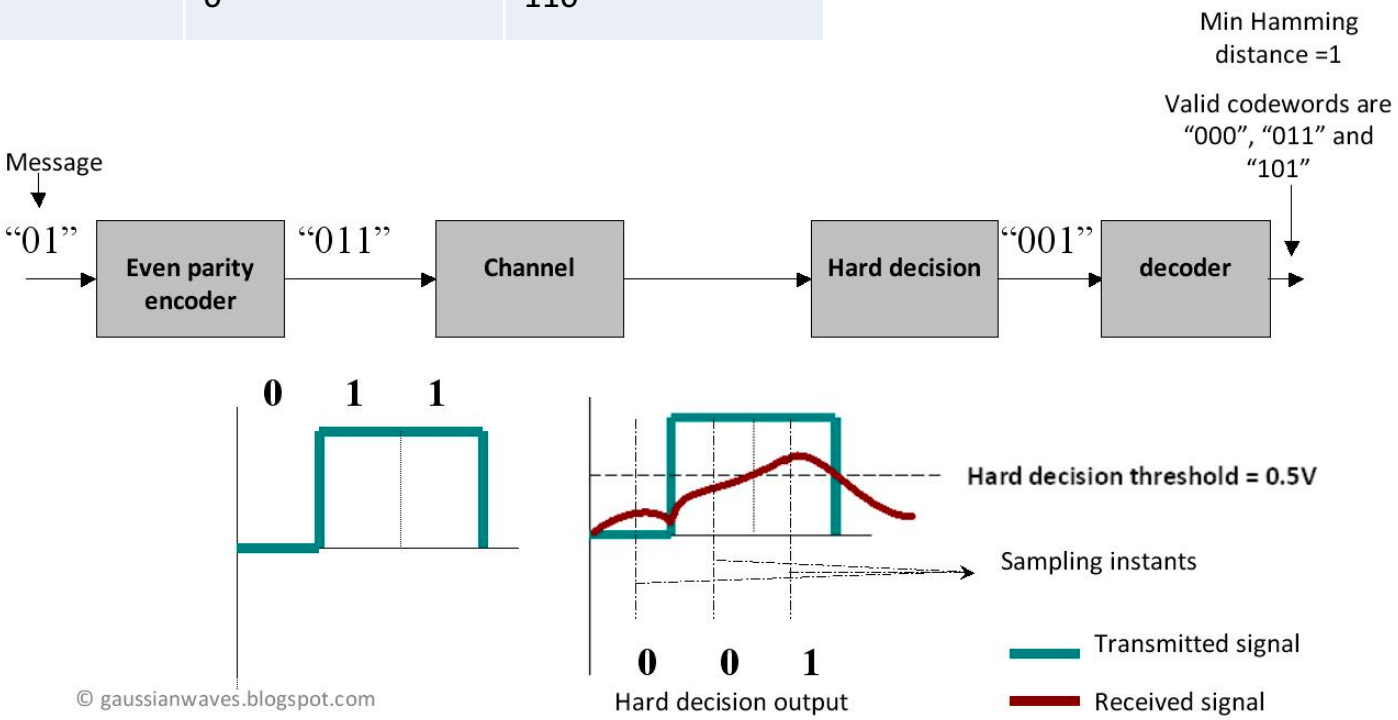
Hybrid ARQ

- Additional HARQ approaches
  - Soft decision decoding
  - Chase combining
    - Soft decision information from a previous frame not corrected by FEC is used with retransmissions
    - *Chase combining* uses exact same frames retransmitted each time
  - Incremental redundancy
    - Different, maybe more, coding used each retransmission
    - Uses less overhead for the first transmissions
    - Provides stronger correction

Soft vs Hard Decision Decoding

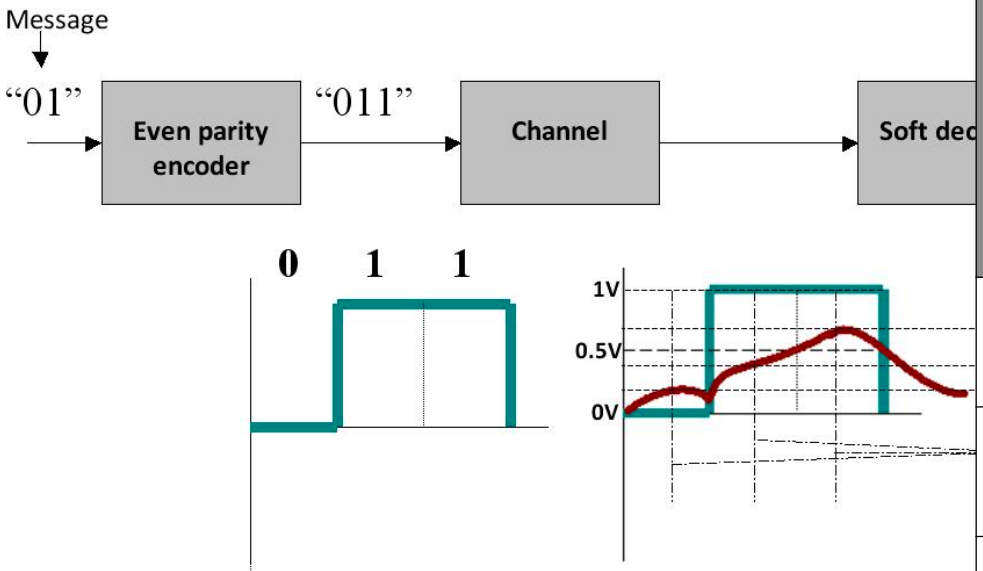
Input Bit 1	Input Bit 2	Parity Bit Added	Codeword
0	0	0	000
0	1	1	011
1	0	1	101
1	1	0	110

Code-words	HD output	Hamming Dist
000	001	1
011	001	1
101	001	1
110	001	3



Source: http://www.gaussianwaves.com/

Soft vs Hard Decision Decoding



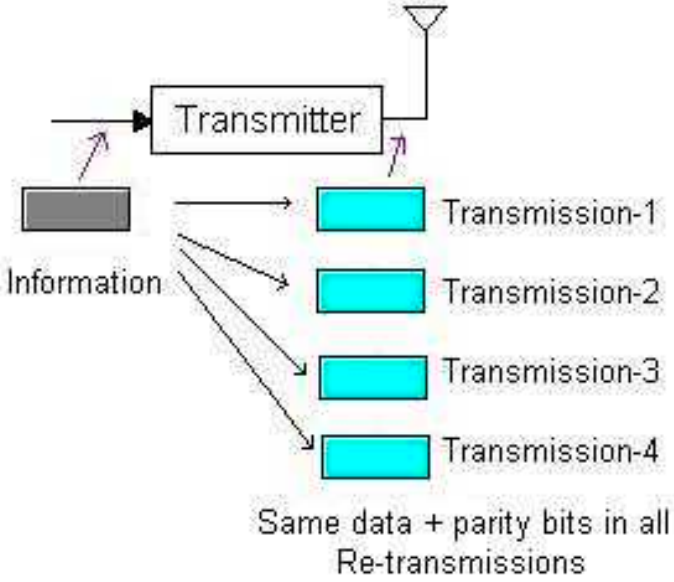
Min Euclidean distance =0.44

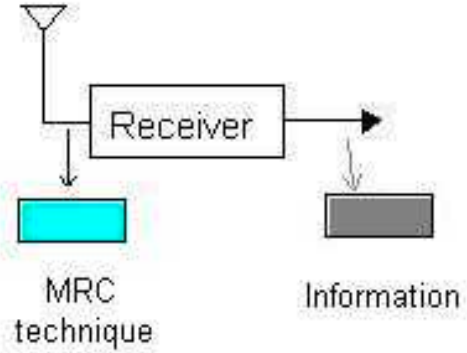
Valid codewords	Voltage levels at each sampling instant of received waveform	Euclidean distance calculation	Euclidean distance
0 0 0 (0V 0V 0V)	0.2V 0.4V 0.7V	$(0-0.2)^2+ (0-0.4)^2+ (0-0.7)^2$	0.69
0 1 1 (0V 1V 1V)	0.2V 0.4V 0.7V	$(0-0.2)^2+ (1-0.4)^2+ (1-0.7)^2$	0.49
1 0 1 (1V 0V 1V)	0.2V 0.4V 0.7V	$(1-0.2)^2+ (0-0.4)^2+ (1-0.7)^2$	0.89
1 1 0 (1V 1V 0V)	0.2V 0.4V 0.7V	$(1-0.2)^2+ (1-0.4)^2+ (0-0.7)^2$	1.49

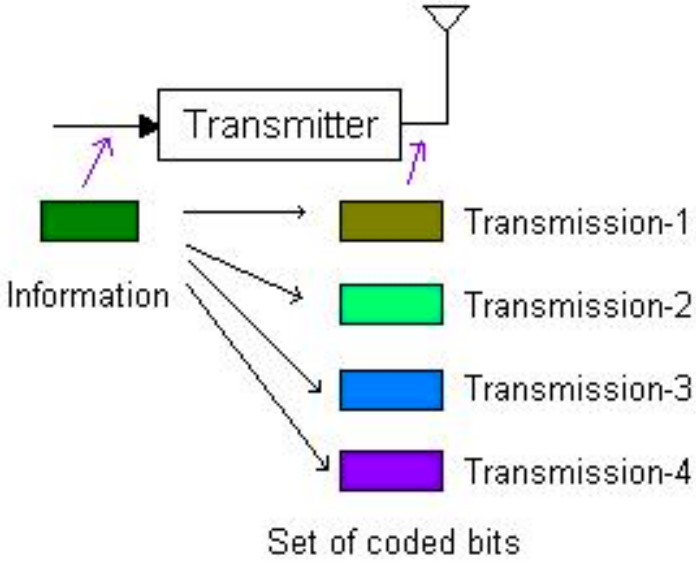
Source: http://www.gaussianwaves.com/

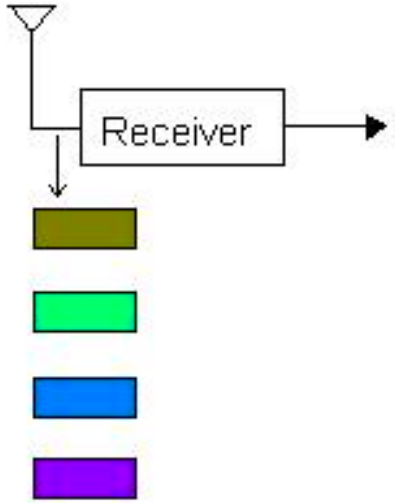
Chase Combining vs Incremental Redundancy

Chase Combining









Incremental Redundancy

Source: http://www.rfwireless-world.com/

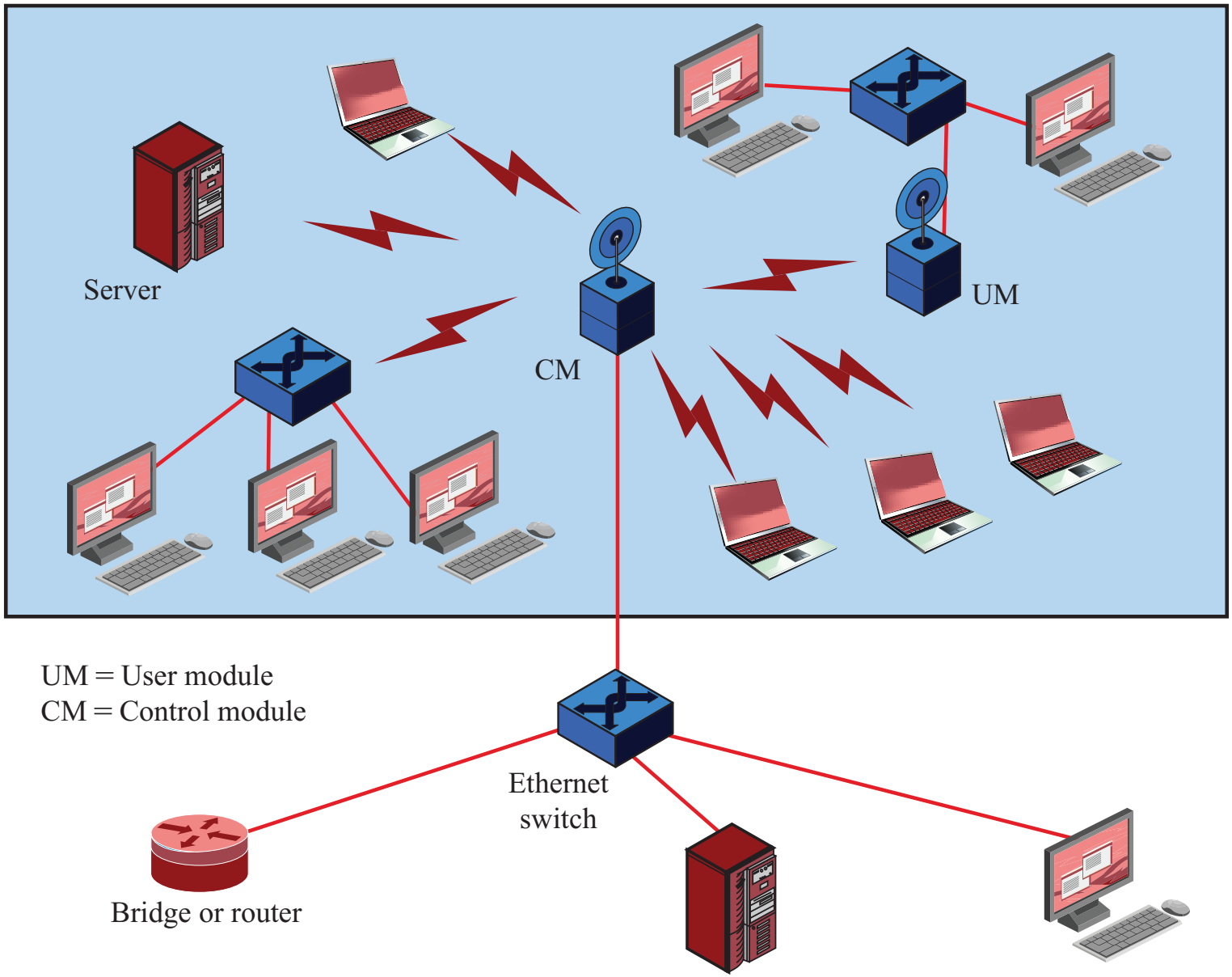
Hybrid ARQ

- Additional approaches
  - Puncturing
    - Remove bits to decrease the coding rate, say from 1/2 to 1/3
    - Replace bits at the receiver with random values
    - Result may still be effective enough to correct errors
    - Allows easier adaptation of coding rates
  - Channel quality information will be used to find the best adaptive modulation and coding for HARQ
  - Parallel HARQ processes can proceed while others are waiting for retransmissions

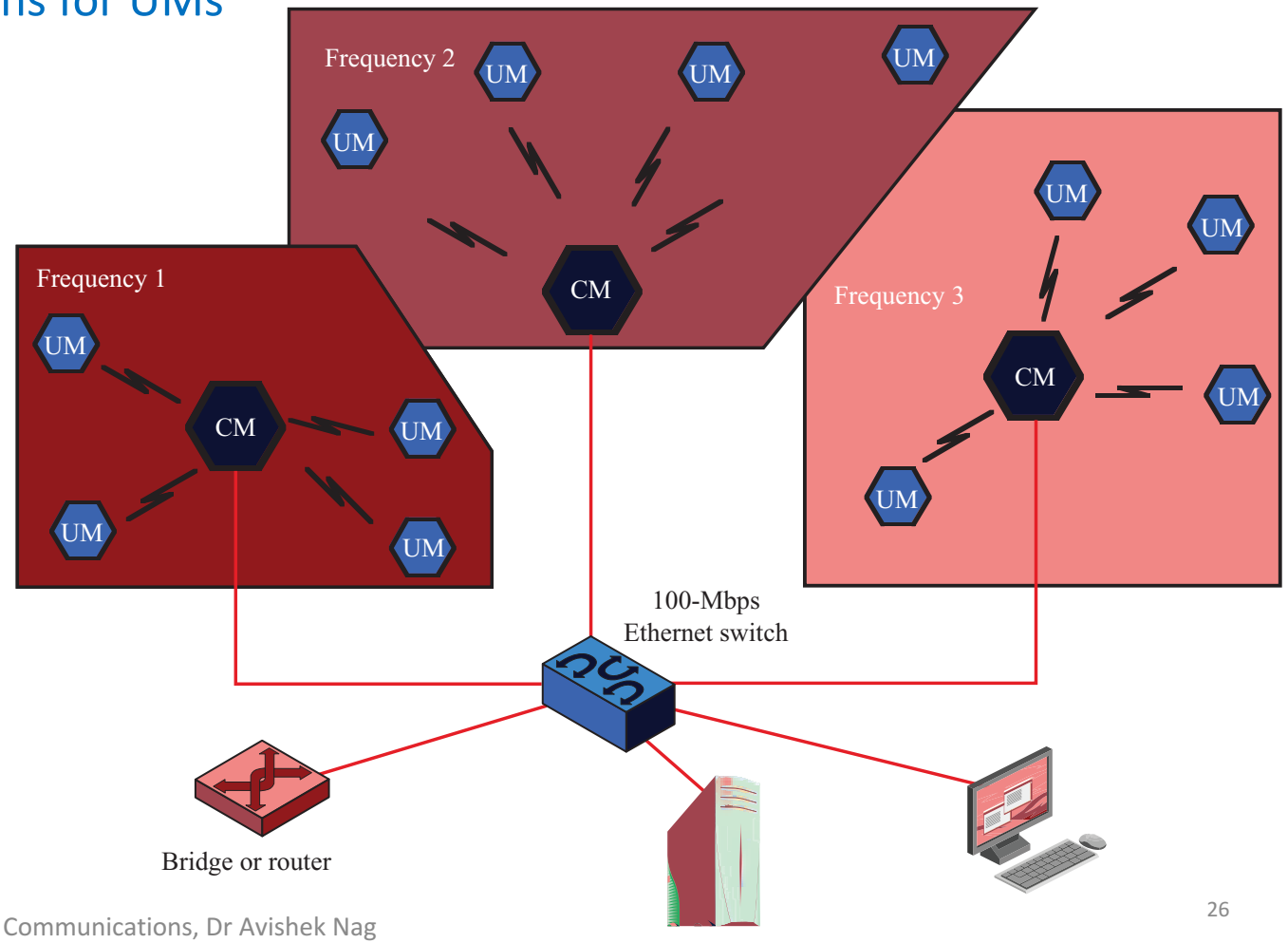
Wireless LAN Technology and the IEEE 802.11 Wireless LAN Standard

Introduction

- Wireless LANs (WLANs)
  - Indispensable adjunct to wired LANs
  - Wireless devices use WLANs
    - As their only source of connectivity
    - Or to replace cellular coverage
- Simple WLAN configuration
  - There is a backbone wired LAN
  - User modules include workstations, servers, devices
  - Control module (CM) interfaces to WLAN
    - Providing bridge or router functionality
    - May have control logic to regulate access
    - May provide wireless connectivity to other wired networks

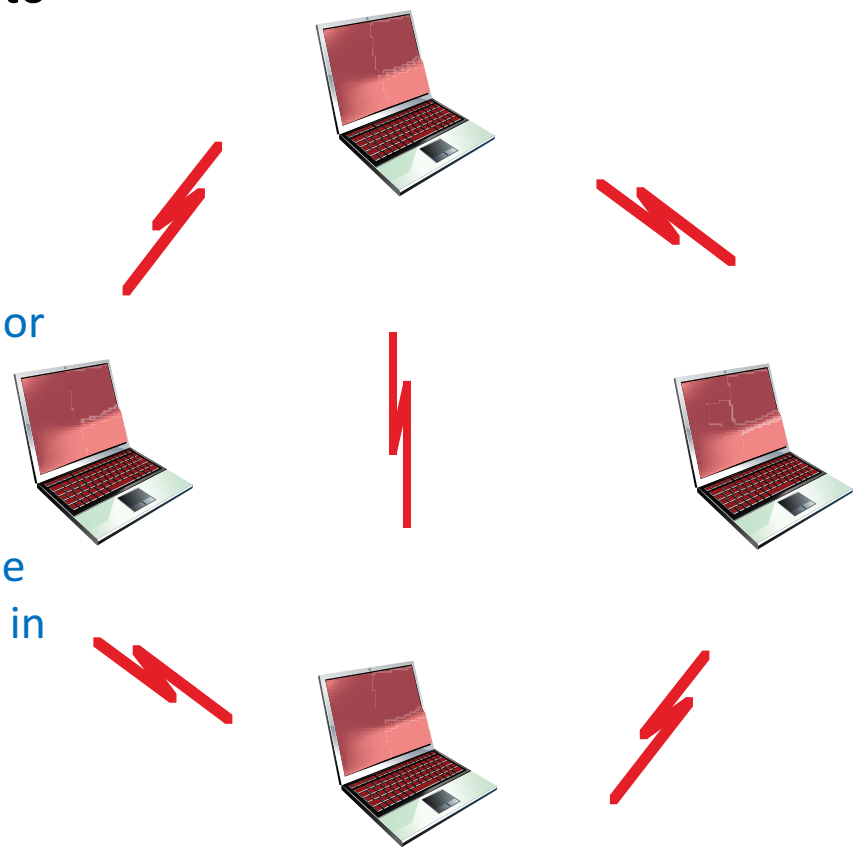

Server
CM
UM
UM = User module
CM = Control module
Ethernet
switch
Bridge or router

- Multiple-cell wireless LAN
  - Multiple CMs connected by a wired LAN
  - Creates many issues for balancing cell loading and providing best connections for UMs



Ad hoc networking

- Temporary peer-to-peer network set up to meet immediate need
  - Peer-to-peer, no centralized server
  - Maybe a temporary network
  - Wireless connectivity provided by WLAN or Bluetooth, ZigBee, etc.
- Example:
  - Group of employees with laptops convene for a meeting; employees link computers in a temporary network for duration of meeting



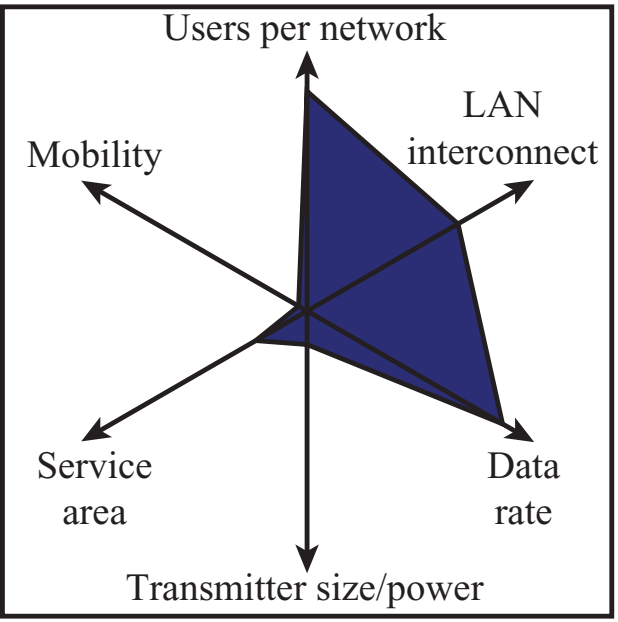
Wireless LAN motivations

- Cellular data offloading
  - WLANs may provide higher data rates and more available capacity
  - Cellular providers may encourage this to offload demand on their networks
- Sync/file transfer
  - Avoid use of cables
- Internet access
- Multimedia streaming

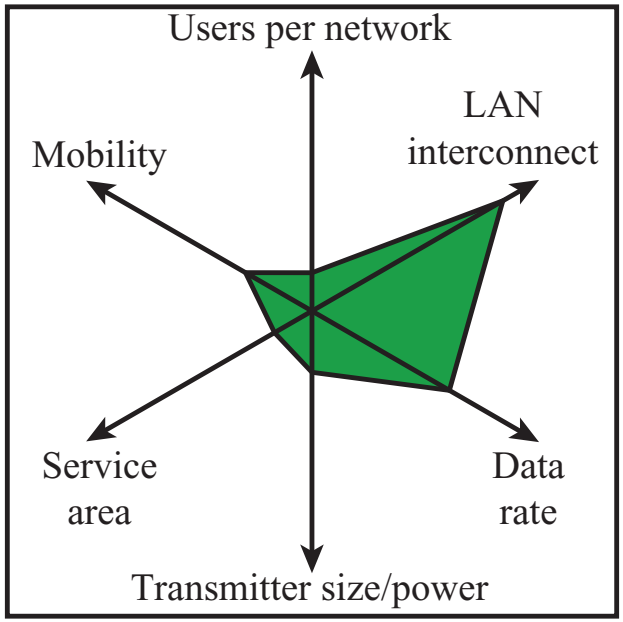
Wireless LAN Requirements

- Throughput
- Number of nodes
- Connection to backbone LAN
- Service area
- Battery power consumption
- Transmission robustness and security
- Collocated network operation
- License-free operation
- Handoff/roaming
- Dynamic configuration

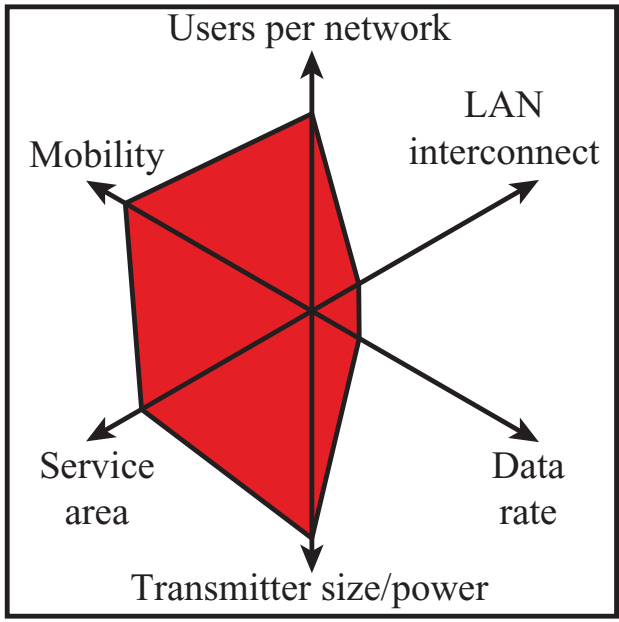
- Comparisons between WLANs, wired LANs, and mobile data networks can be visualized with Kiviat graphs.



(a) Wired LANs



(b) Wireless LANs



(c) Mobile data networks