Mobile Ad Hoc Networks

Implementation Issues

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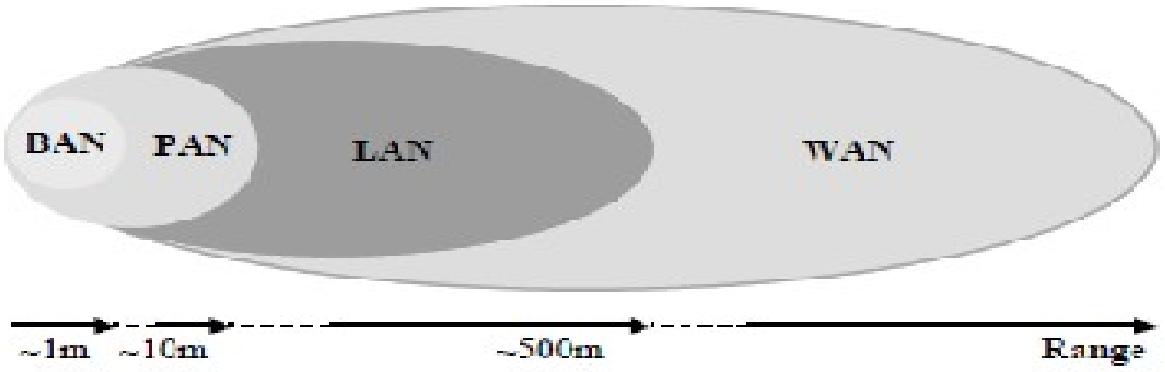
Mobile Ad Hoc Network

- A mobile ad hoc network (MANET) represents a system of wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary network topologies, allowing people and devices to seamlessly internetwork in areas without any preexisting communication infrastructure.
- A network with a transmission range of a human body, i.e., a Body Area Network(BAN), constitutes the best solution for connecting wearable devices.
- "*ambient intelligence*" ->Ability of the technology to adapt itself to the user without requiring that users modify their behavior and knowledge.
- The new trend is to help users in everyday life by exploiting technology and infrastructures that are hidden in the environment and do not require any major change in the users' behavior.



Ad hoc networks taxonomy.

Mobile Ad Hoc Network

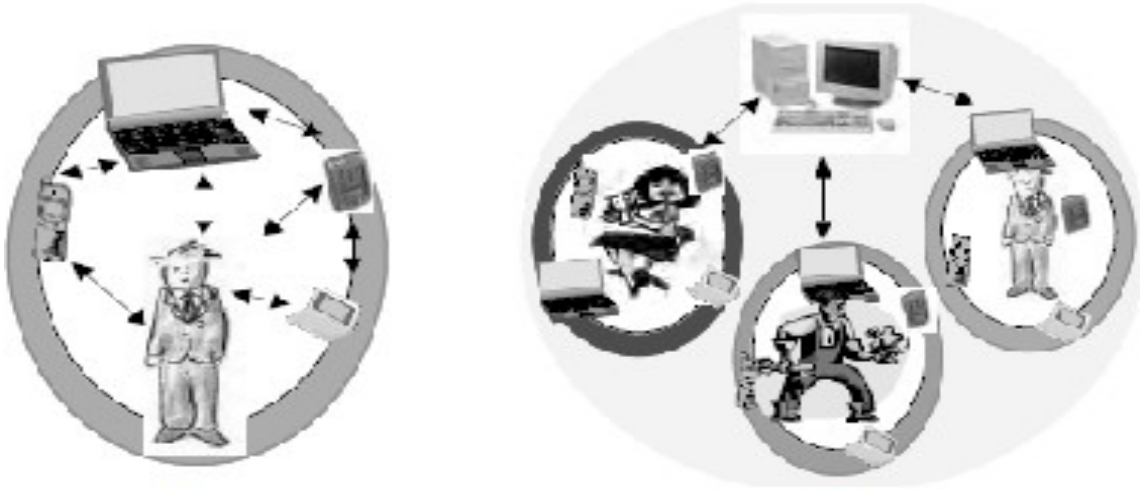
- People and vehicles can thus be internetworked in areas without a preexisting communication infrastructure or when the use of such infrastructure requires wireless extension
- We can classify ad hoc networks, depending on their coverage area, into four main classes: Body, Personal, Local, and Wide Area Networks.
- These technologies constitute the building blocks to construct small multi-hop ad hoc networks that extend the range of the ad hoc networks' technologies over a few radio hops

Body Area Network

- A Body Area Network is strongly correlated with wearable computers. The components of a wearable computer are distributed on the body (e.g., head-mounted displays, microphones, earphones, etc.), and a BAN provides the connectivity among these devices
- Main requirements of a BAN are
  - The ability to interconnect heterogeneous devices, ranging from complete devices (e.g., a mobile phone) to parts of a device (microphone, display, etc.)
  - Autoconfiguration capability (Adding or removing a device from a BAN should be transparent to the user.)
  - Services integration (Data transfer of audio and video must coexist with non–real time data, e.g., Internet data traffic.)
  - The ability to interconnect with the other BANs (to exchange data with other people) or PANs(e.g., to access the Internet)

Personal Area Network

- Personal area networks connect mobile devices carried by users to other mobile and stationary devices.
- A PAN communicating range is typically up to 10 meters, thus enabling
  - The interconnection of the BANs of people close to each other
  - The interconnection of a BAN with the environment around it
- Wireless PAN (WPAN) technologies in the 2.4 GHz ISM band are the most promising technologies for widespread PAN deployment. Spread spectrum is typically employed to reduce interference and utilize the bandwidth

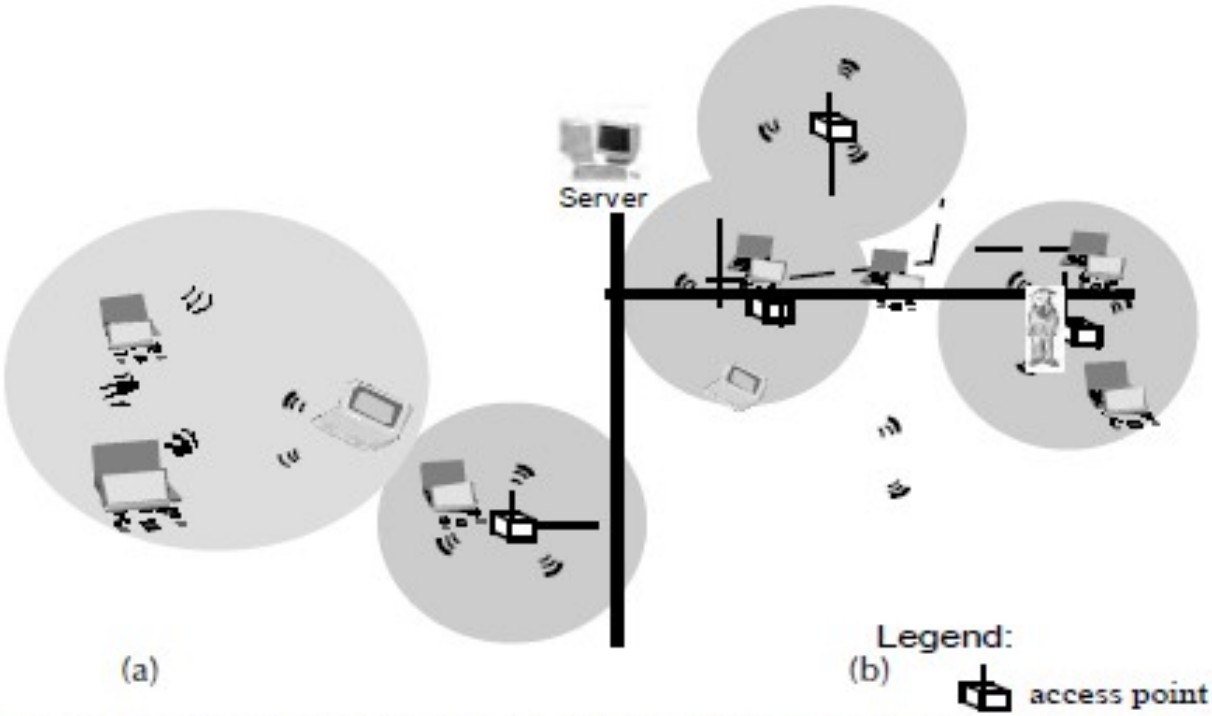


(a) (b)

Relationship between a Body (part a) and a Personal Area Network (part b).

Wireless Local Area Network

- A WLAN should satisfy the same requirements typical of any LAN, including high capacity, full connectivity among attached stations, and broadcast capability. However, to meet these objectives, WLANs should be designed to face some issues specific to the wireless environment, such as security on the air, power consumption, mobility, and bandwidth limitation of the air interface



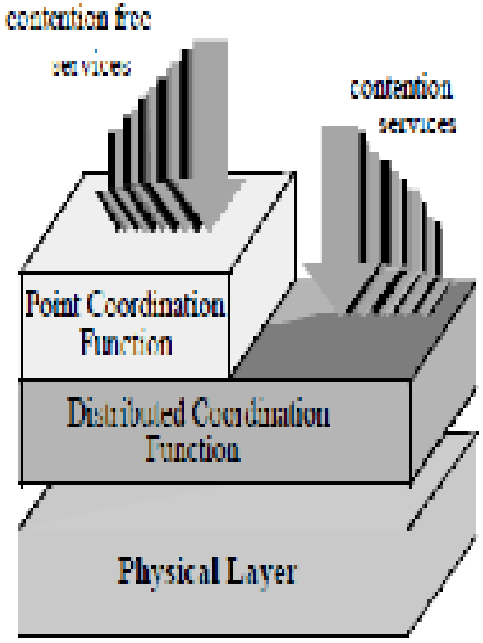
WLAN configurations: (a) ad hoc networking; (b) infrastructure-based

Technologies for Ad Hoc Networks

- Currently, two main standards are emerging for ad hoc wireless networks: the IEEE 802.11 standard for WLANs and the Bluetooth specifications for short-range wireless communications
- Multi-hop networks covering areas of several square kilometers could also be built by exploiting the IEEE 802.11 technology.
- On smaller scales, technologies such as Bluetooth can be used to build ad hoc wireless Body and Personal Area Networks
- Here we present the architecture and protocols of IEEE 802.11 and Bluetooth. In addition, the performances of these technologies are analyzed. Two main performance indices will be considered: the throughput and the delay.
- As far as throughput is concerned, special attention will be paid to the Medium Access Control (MAC) protocol capacity , defined as the maximum fraction of channel bandwidth used by successfully transmitted messages.
- Since a WLAN relies on a common transmission medium, the transmissions of the network stations must be coordinated by the MAC protocol.
- The delay can be defined in several forms (access delay, queuing delay, propagation delay, etc.) depending on the time instants considered during its measurement

IEEE 802.11 Architecture and Protocols

- The IEEE 802.11 standard specifies a MAC layer and a physical layer for WLANs
- MAC layer provides to its users both contention-based and contention -free access control on a variety of physical layers.
- Specifically, three different technologies can be used at the physical layer: infrared, frequency hopping spread spectrum, and direct sequence spread spectrum
- The basic access method in the IEEE 802.11 MAC protocol is the Distributed Coordination Function (DCF), which is a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) MAC protocol.
- Besides the DCF, the IEEE 802.11 also incorporates an alternative access method known as the *Point Coordination Function* (PCF). The PCF operates similarly to a polling system , a point coordinator provides (through a polling mechanism) the transmission rights at a single station at a time.
- For mobile ad hoc networks, we will focus only on DCF as PCF cannot be used.

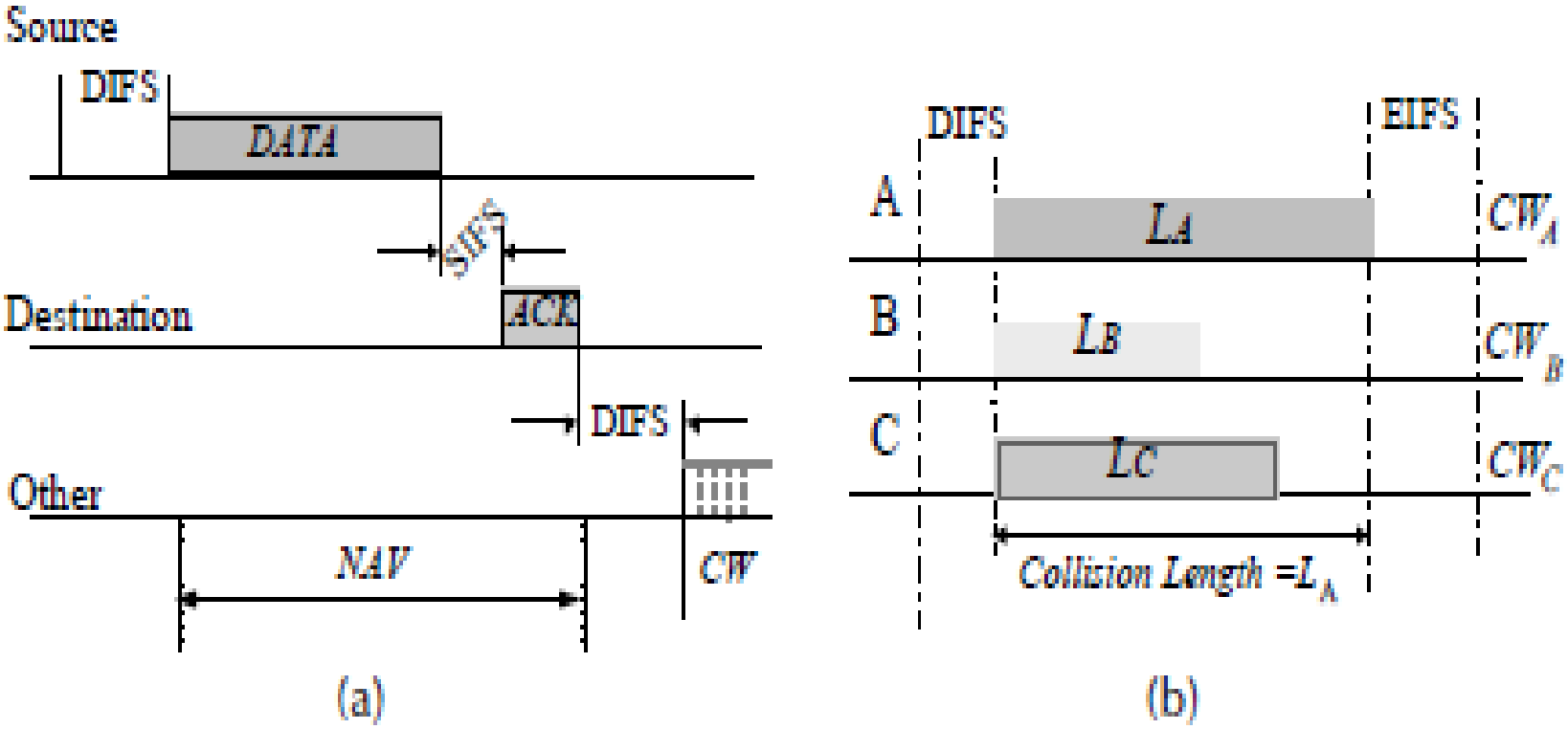


IEEE 802.11 architecture.

IEEE 802.11 DCF

- When using the DCF, before a station initiates a transmission, it senses the channel to determine whether another station is transmitting.
- If the medium is found to be idle for an interval that exceeds the *Distributed InterFrame Space* (DIFS), the station continues with its transmission
- The transmitted packet contains the projected length of the transmission.
- Each active station stores this information in a local variable named *Network Allocation Vector* (NAV). Therefore, the NAV contains the period of time the channel will remain busy
- Immediate positive acknowledgments are employed to ascertain the successful reception of each pack et transmission
- The receiver after the reception of the data frame waits for a time interval, called the *Short InterFrame Space* (SIFS), which is less than the DIFS, and then initiates the transmission of an acknowledgment (ACK) frame
- A Cyclic Redundancy Check (CRC) algorithm is adopted to discover transmission errors.
- After an erroneous frame is detected (due to collisions or transmission errors), the channel must remain idle for at least an Extended InterFrame Space (EIFS) interval before the stations reactivate the backoff algorithm to schedule their transmissions
- Backoff Alogrithm

IEEE 802.11 DCF



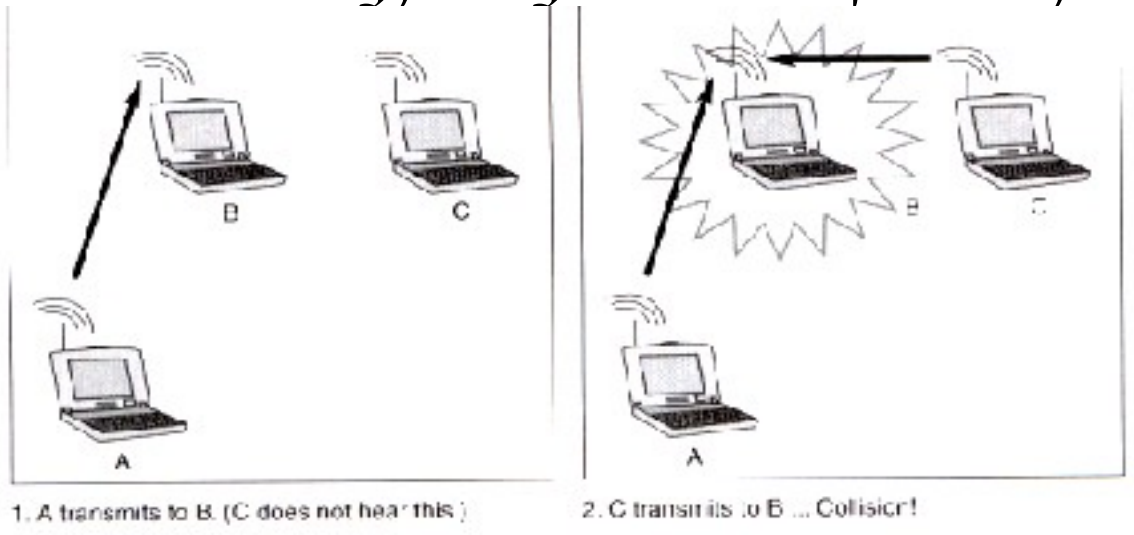
IEEE 802.11 DCF: (a) a successful transmission; (b) a collision.

IEEE 802.11

- In the IEEE 802.11 standard, an ad hoc network is called an *Independent Basic Service Set* (IBSS) .
- An IBSS enables two or more IEEE 802.11 stations to communicate directly without requiring the intervention of a centralized access point or an infrastructure network.
- The IEEE 802.11 uses two main functions for the synchronization o f the stations in an IBSS: (1) synchronization acquisition and (2) synchronization maintenance.
- ***Synchronization Acquisition*** — *This functionality is necessary for joining an existing IBSS. The* discovery of existing IBSSs is the result of a scanning procedure of the wireless medium. During the scanning, the station receiver is tuned on different radio frequencies, searching for particular control frames
- ***Synchronization Maintenance*** — *Because of the lack of a centralized station that provides its own* clock as common clock, the synchronization function is implemented via a distributed algorithm that shall be performed by all of the members of the IBSS

IEEE 802.11 RTS/CTS

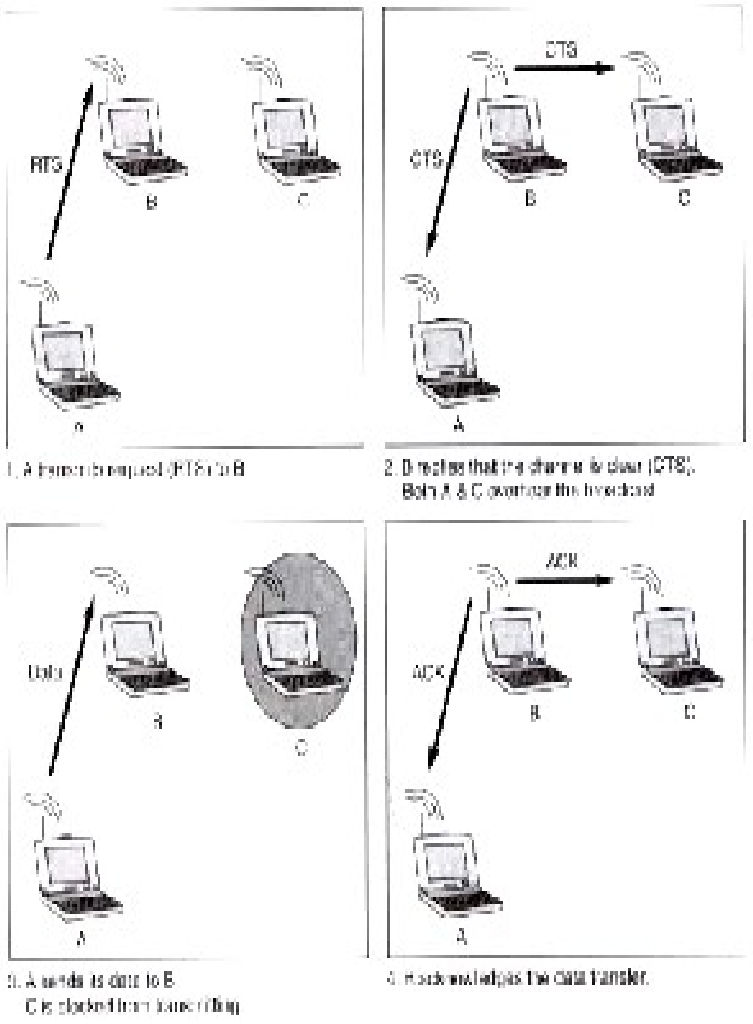
- Hidden Terminal Problem
  - Two nodes are said to be hidden from each other and try to send data to same receiving node → Collision
  - How to solve this problem
    - All receiver's neighboring nodes are informed that channel



1. A transmits to B. (C does not hear this.)

2. C transmits to B ... Collision!

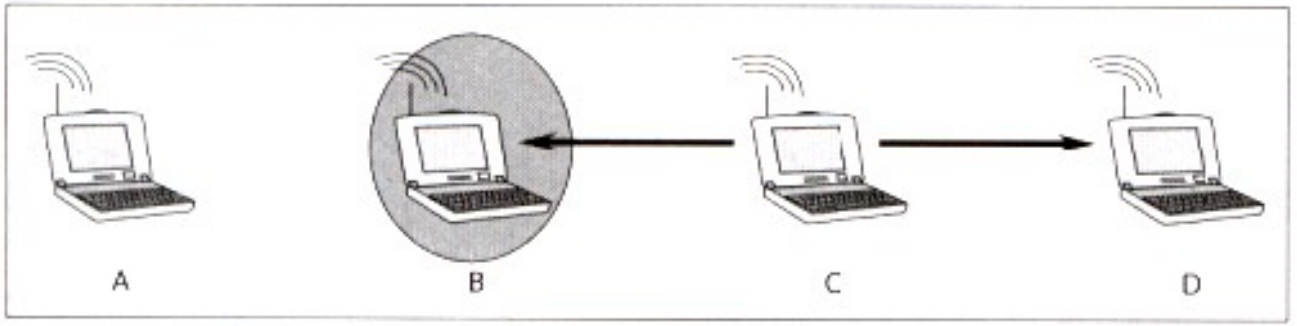
- RTS-CTS Solution
  - Sender send RTS message to receiver
  - Receiver send CTS message back using broadcast
  - All neighboring nodes ge it
  - Receiver sends ACK back using broadcast
- Shortcoming → RTS-CTS Solution
  - There can still be collision
  - What if Receiver is sending a CTS message and another neighboring node sending RTS message at the same time



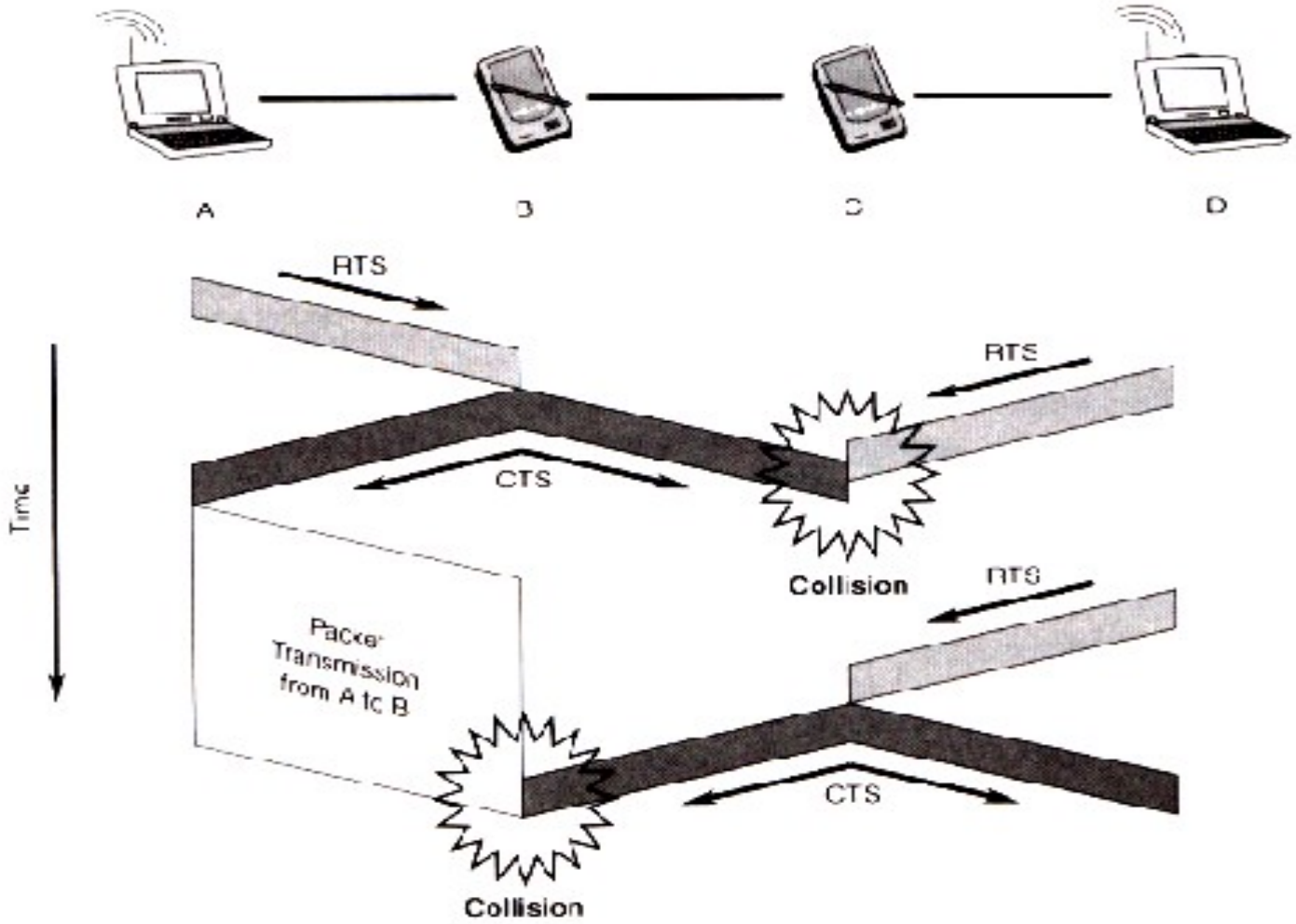
Exposed Node Problem

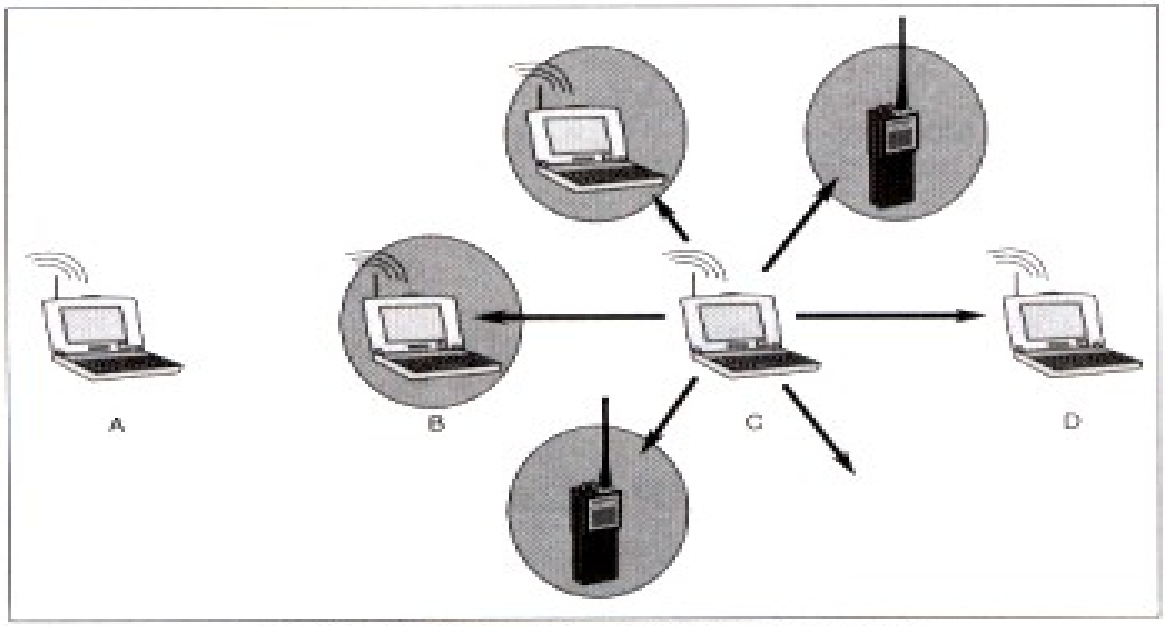
- Overhearing a data transmission from neighboring nodes can inhibit one node from transmitting to another node
  - An exposed node in the range of transmitter

- Solution
  - Use of separate control and data channels
  - Use of directional antennas

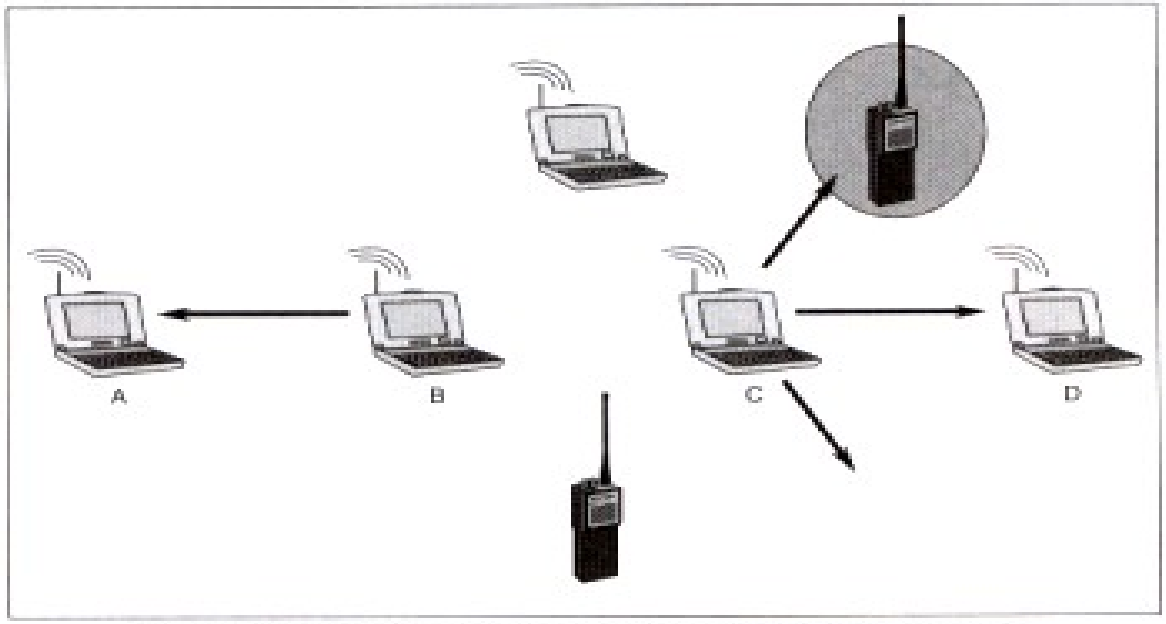


- C is transmitting to D.
- B overhears this, and is blocked.
- B wants to transmit to A, but is being blocked by C.
- Wasted bandwidth!

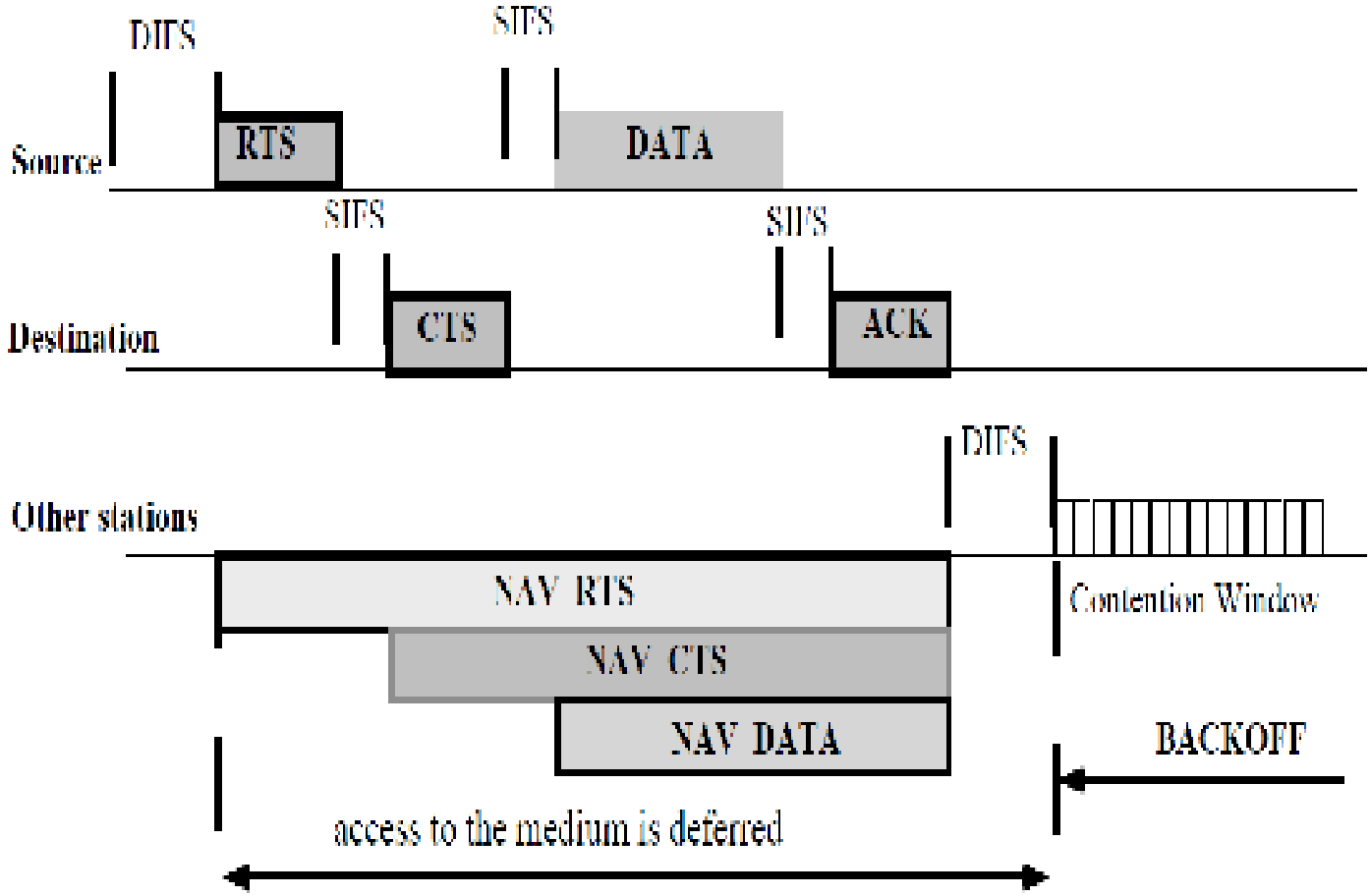

A
B
C
D
RTS
RTS
CTS
Collision
RTS
Packet Transmission from A to B
CTS
Collision
Time



Omni-directional antenna used. All neighbors are exposed.



Directional antenna reduces this problem! B is not blocked from sending to A.



The RTS/CTS mechanism.

A Bluetooth Network

- From a logical standpoint, Bluetooth belongs to the contention-free token-based multi-access networks
- In a Bluetooth network, one station has the role of master, and all other Bluetooth stations are slaves.
- The master decides which slave has access to the channel
- The units that share the same channel (i.e., are synchronized to the same master) form a *piconet, the fundamental building block of a Bluetooth* network.
- A piconet contains a master station and up to seven *active (i.e., participating in data exchange) slaves.*
- Stations with *Parking state are stations that are synchronized with the master but are not* participating in any data exchange
- The complete Bluetooth protocol stack contains several protocols: Bluetooth radio, Baseband, Link Manager Protocol (LMP), Logical Link Control and Adaptation Protocol (L2CAP), and Service Discovery Protocol (SDP).
- Bluetooth radio provides the physical links among Bluetooth devices, while the Baseband layer provides a transport service of packets on the physical links
- The L2CAP services are used only for data transmission. The main features supported by L2CAP are protocol multiplexing (the L2CAP uses a protocol type field to distinguish between upper layer protocols) and segmentation and reassembly.