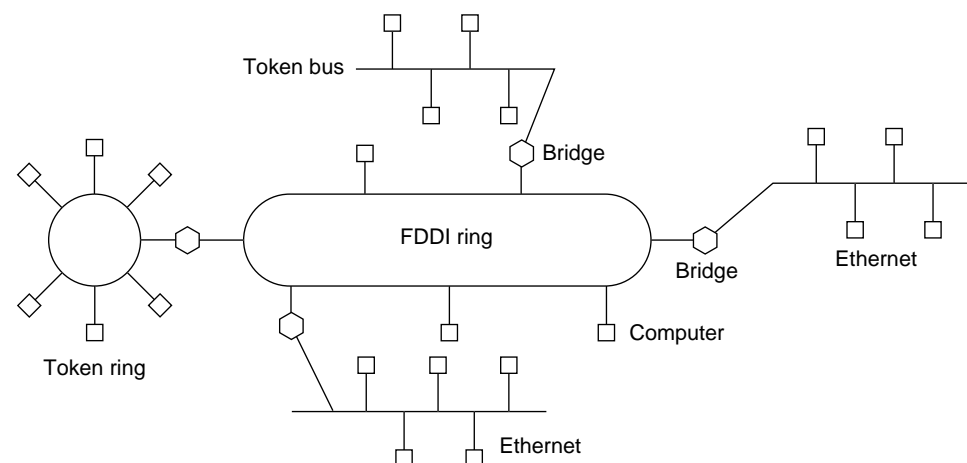# Fiber Distributed Data Interface

- **FDDI**: is a 100 Mbps fiber optic timed token ring LAN Standard, over distance up to 200 km with up to 1000 stations connected, and is useful as backbone

- FDDI uses a dual ring topology and some other mechanisms, such as station bypass, to enhance fault tolerance

- **Timed token ring**: let token rotation time

  be TRT, target TRT be TTRT, and token holding time be THT

  ```
  Asynchronous class traffic (such as computer data)
      If TRT > TTRT (token is late): no transmission;
      If TRT < TTRT (token is early): transmission limited to THT = TTRT - TRT.
  Synchronous class traffic (such as voice data)
      Transmission, but THT is small and fixed so: worst case TRT < 2 TTRT
  ```
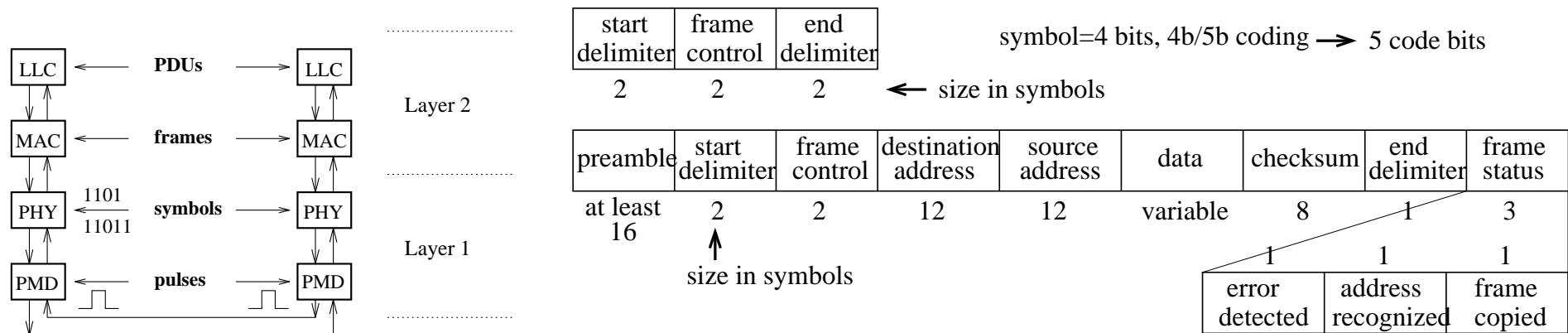
  Note this is different from usual token ring, such as 802.5

- Token is released immediately after frame has been sent (In 802.5, token is released after frame has back to sender)

Medium Access Control for FDDI

- **FDDI protocols**, and MAC token and frame formats:

start delimiter	frame control	end delimiter
2	2	2

← size in symbols

symbol=4 bits, 4b/5b coding → 5 code bits

Layer 2

preamble	start delimiter	frame control	destination address	source address	data	checksum	end delimiter	frame status
at least 16	2	2	12	12	variable	8	1	3

size in symbols

	1	1	1
	error detected	address recognized	frame copied

Layer 1

LLC ← PDUs → LLC

MAC ← frames → MAC

PHY ← $\frac{1101}{11011}$ symbols → PHY

PMD ← pulses → PMD

- **Frame control**:

  - 1st bit indicates class of services, 0/1=asynchronous/synchronous

  - 2nd bit indicates length of address, 0/1=16/48 bits of address (16 bits address is now redundant)

  - Rest of 6 bits indicate frame types, including LLC frames given to MAC for transmission (in this case, the last 3 bits are for priorities), MAC frames used by MAC for ring maintenance and fault recovery, and station management frames

- **Frame status**: A and C are the same as in token ring, and E (error detected) is reset to logic 0 at sender → each user on ring can check frame and, if any error is detected, it sets E to logic 1

Medium Access by Reservation Overview

- **Multiple access** techniques include frequency or wavelength division multiple access, time division multiple access, code division multiple access, and space division multiple access

  - FDMA or WDMA: total system bandwidth (wavelength) is divided into narrow frequency (wavelength) slots (channels). Each user is allocated a unique band or channel

    A user is free to transmit or receive all the time on its allocated channel, but the cost of transceiver is high, as each has to be designed on a different band, e.g. 1G mobile system

  - TDMA: time frame is divided into slots (channels). Each user is allocated a particular time slot or channel

    A user is limited to transmit or receive only regular bursts of a wideband signal, but it takes advantages of digital technologies, e.g. 2G mobile system

  - CDMA: user data is spread by high-rate chip sequences to entire system bandwidth. Each user is allocated a unique code sequence

    Hardware requires high-rate electronics, but this technology offers much higher capacity and many advantages, e.g. 3G mobile system

  - SDMA: utilises spatial diversity. Users can have same carrier (channel), but as long as they have different angles of arrival, they can be separated by smart antenna with adaptive beamforming

    This technology provides potential for further improving bandwidth efficiency, future 4G?

Medium Access Techniques (continue)

- For most WANs, FDMA will always be there to divide allocated total system bandwidth into frequency slots (channels)

- FDMA, WDMA and TDMA have hard capacity, no more user can access after reaching the capacity while CDMA and SDMA have soft capacity, allow more users at gradually degraded quality

- A channel is a frequency or wavelength slot for FDMA or WDMA system, a time slot in TDMA system, or a channelisation code in CDMA system

- Channels are dynamically allocated and how to make a reservation to gain access may involve a contention process (reservation by contention), more specifically

  – A system has a set of **user channels** and some separate **signalling channels**
  – To gain access to the system is to be given a user channel, and "booking" is done by some signalling channels
  – To let system know you want to make a call or book a user channel first needs to reserve a signalling channel via some random access channel, typically using ALOHA type algorithm
  – This is the access strategy used for 2G GSM and 3G CDMA mobile systems
  – For example, in CDMA system, to make request for access is to transmit it with a specific code (random access channel): if successful, you'll be given one signalling code (channel); if unsuccessful, i.e. collision due to some one is doing the same thing (trying to gain access), you have to wait and try again – a ALOHA type contention procedure

WDMA LAN

- In this kind of fiber optics LANs, a channel is a wavelength band

- A user gets two channels: control and data. A channel has fixed time slots, and data channel's last slot contains information on free slots in its control channel

- B communicates with A using variable rate connection-oriented:

  - To contact A, B reads status slot in A's data channel to see A has any control slots unused; then makes Tx request in a free slot in A's control channel

  - If A accepts Tx request, B can send data on a specific slot of its own data channel and tell A where to pick up

  - If B and C both try to grab a same control slot of A's at same time, a failure is given in A's status slot $\rightarrow$ B and C have to wait a random period of time before try again (contention)

- Constant rate connection-oriented: when B asks for connection, it also asks "can I send you a frame in every occurrence of slot 2?" If accepted, a guaranteed bandwidth connection is established. if not, B tries a different proposal
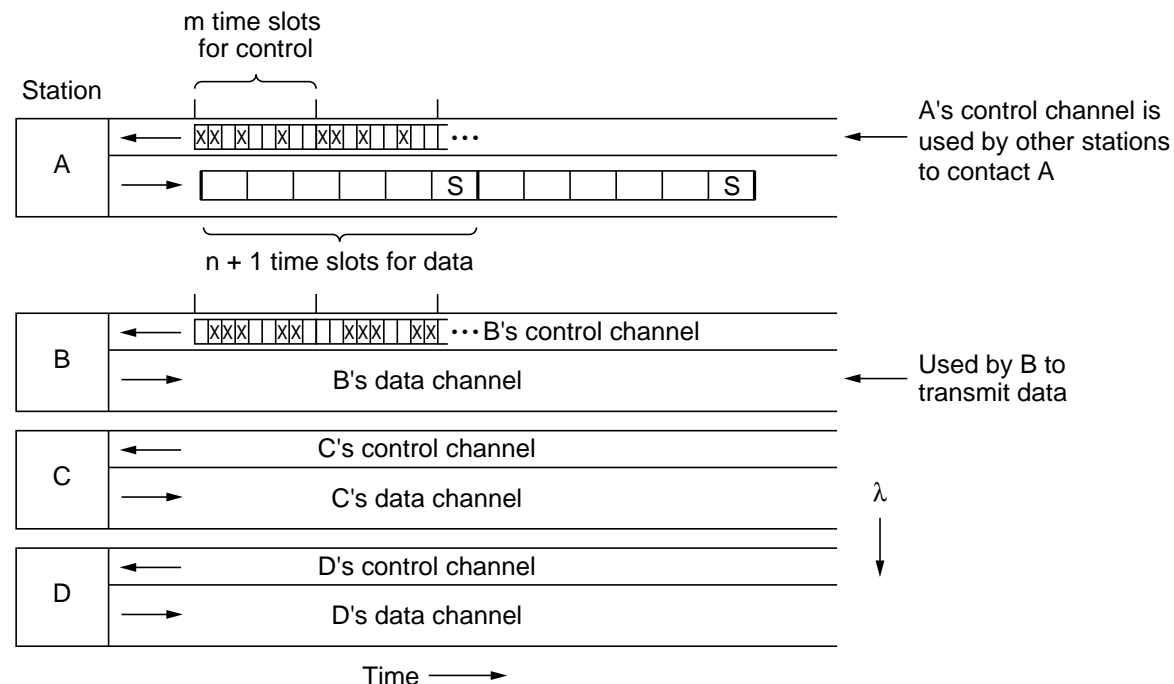
Digital Cellular Radio

- The concepts of cells and frequency reuse are fundamental to cellular radio. A cell maintains a set of frequency slots (channels). Two cells separated by a sufficiently long distance may use the same set of frequency slots (co-channels). This greatly improves bandwidth efficiency

(a)   (b)
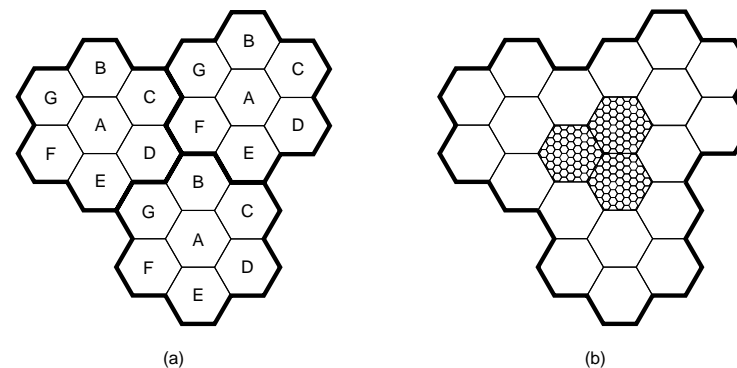
- **GSM**: global systems for mobile communications uses a mixture of FDMA and TDMA technologies

GSM has 124 downlink channels and 124 uplink channels (FDM) per cell. Each such channel has a frequency band of 200 kHz and can support 8 separate users (TDM). Theoretically, there are $8 \times 124 = 992$ fully duplex (downlink/uplink) channels per cell, but many of them may not be used for avoiding co-channel interference with neighboring cells
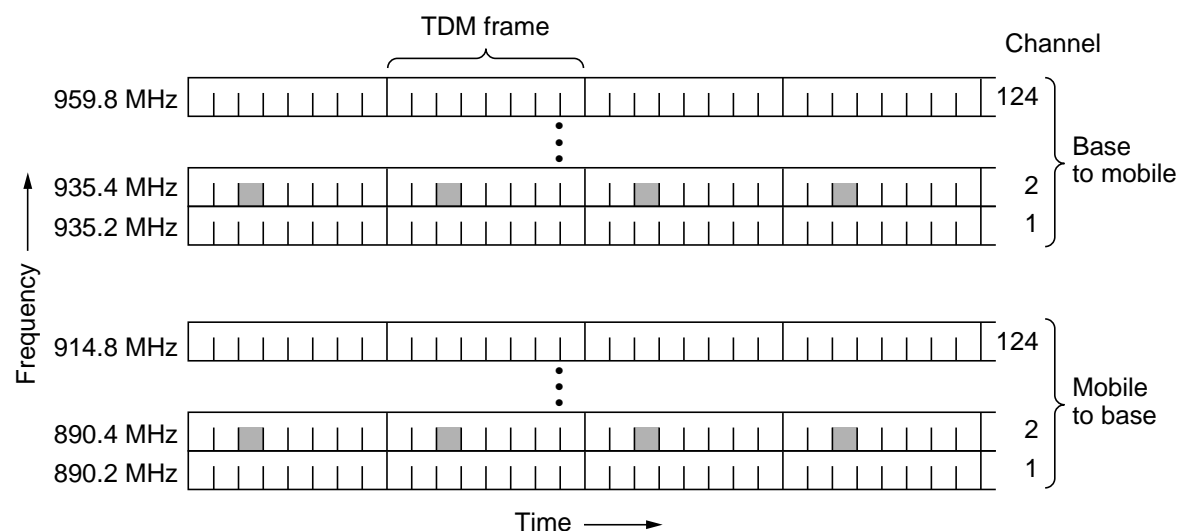
GSM Control Channels

The above approximately 1000 channels are user channels, and GSM has some separate signalling (control) channels

- **Broadcast control channel**: continuously broadcasts the base identity and the channel status. By monitoring this channel, mobile knows which cell it is in

- **Dedicated control channel**: is for location updating, registration, and call setup. Through this channel, a base knows who are in its cell

- Common control channel: consists of three logic sub-channels

  - **Paging channel**: is used by the base to announce incoming calls. Mobile continuously monitors this channel to see any call for it
  - **Random access channel**: is used by mobile to request a slot on the dedicated control channel, for call setup
    The access to the random access channel is based on slotted ALOHA
  - **Access grant channel**: is used to announce the assigned slot (who is granted access to which slot of the dedicated control channel)

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Wireless LANs

- Considers wireless LANs that use packet radio with short range. Typically there is a single channel covering the entire bandwidth (a few Mbps) – Note no central access point and it is ad hoc network

- CSMA would not work because:

  Hidden station problem: when A is transmitting to B, if C senses the medium, it will falsely conclude that it can transmit, as it cannot hear A
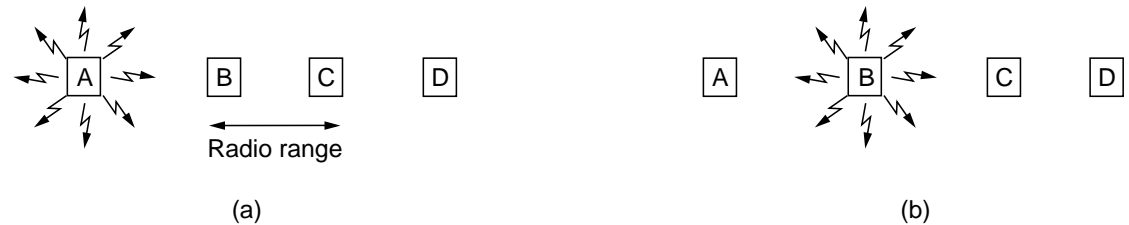
  Exposed station problem: when B is transmitting to A, if C senses medium, it hears an ongoing transmission and falsely concludes that it may not transmit to D, but in fact it can safely do so
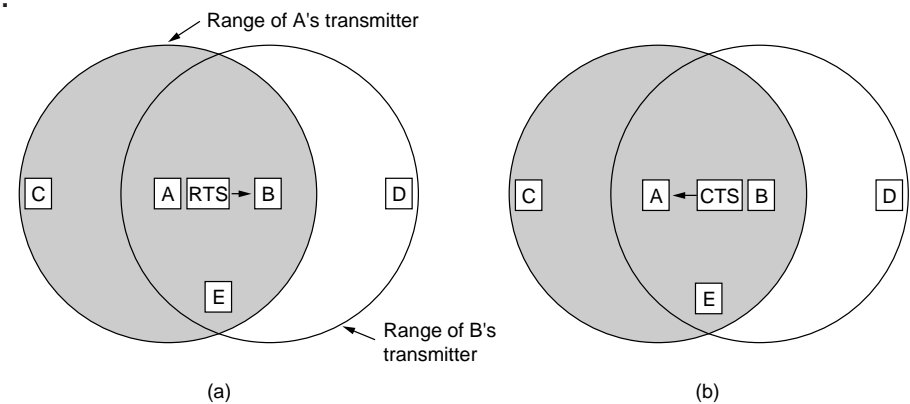
- Multiple access with collision avoidance (MACA): **sense activity around intended receiver**. Consider that A is trying to communicate with B:

  A transmits a Request to Send (RTS) to B
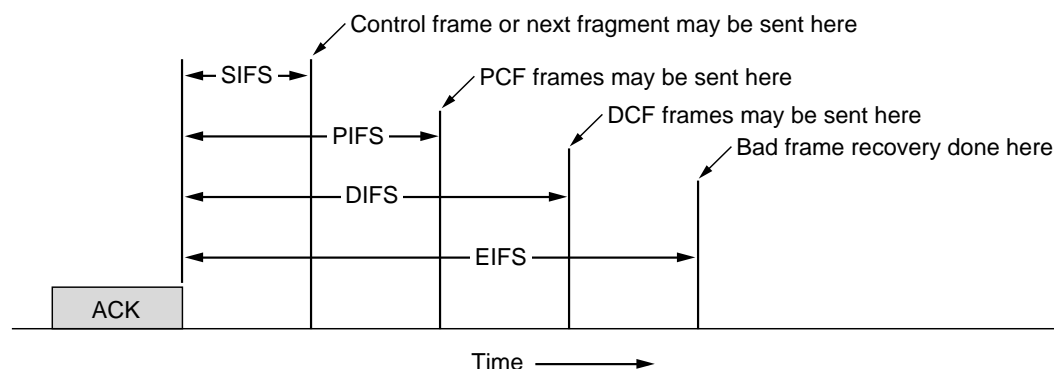
  B answers with a Clear to Send (CTS)

  C can hear the RTS from A but not the CTS from B, and it can freely transmit

  D hears only CTS from B, and must keep silent

IEEE 802.11 Medium Access Control

- Two modes of operation: **distributed coordination function** with no central control (access point), and **point coordination function** with base station controlling activities in its cell

- For **DCF**, medium access control protocol is based on MACA (multiple access with collision avoidance)
  - To cope with noisy wireless channels, 802.11 allows frames to be fragmented into smaller pieces, each with its own checksum
  - Fragments are individually numbered and acknowledged using stop-and-wait
  - Once channel has been acquired using RTS and CTS, multiple fragments can be sent in row

- For **PCF**, base station polls users, asking them if they have frames to send and controls transmission order $\rightarrow$ no collision, a signed up user is guaranteed a certain fraction of bandwidth
  - Base periodically broadcasts a beacon frame, which contains system parameters, such as hopping frequencies and dwell times (for FHSS), clock synchronisation, etc., and it also invites new users to sign up for polling service

- 802.11 lets PCF and DCF to co-exist within a cell by carefully defining **interframe time interval**: after a frame has been sent, a certain dead time is required before any user may sent frame

Control frame or next fragment may be sent here

PCF frames may be sent here

DCF frames may be sent here

Bad frame recovery done here

SIFS

PIFS

DIFS

EIFS

ACK

Time

802.11 Frame Structure

- **Frame control**: has 11 subfields
  - Protocol version: two versions of protocol are allowed in same cell
  - Type: indicates data, control or management
  - Subtype: e.g. RTS, CTS or ACK

Bytes	2	2	6	6	6	2	6	0-2312	4
	Frame control	Dur-ation	Address 1	Address 2	Address 3	Seq.	Address 4	Data	Check-sum

Bits	2	2	4	1	1	1	1	1	1	1	1	
	Version	Type	Subtype	To DS	From DS	MF	Re-try	Pwr	More	W	O	Frame control

  - To DS and from DS: indicate frame is going to or coming from the intercell distribution system
  - MF: more fragments will follow
  - Retry: marks a retransmission of a frame sent early
  - Power management: is used by base to put receiver to sleep state or take it out of sleep state
  - More: indicate sender has more frames to send
  - W: indicates that frame body has been encrypted using wired equivalent privacy
  - O: tells receiver that a sequence of frames with this bits on must be processed strictly in order
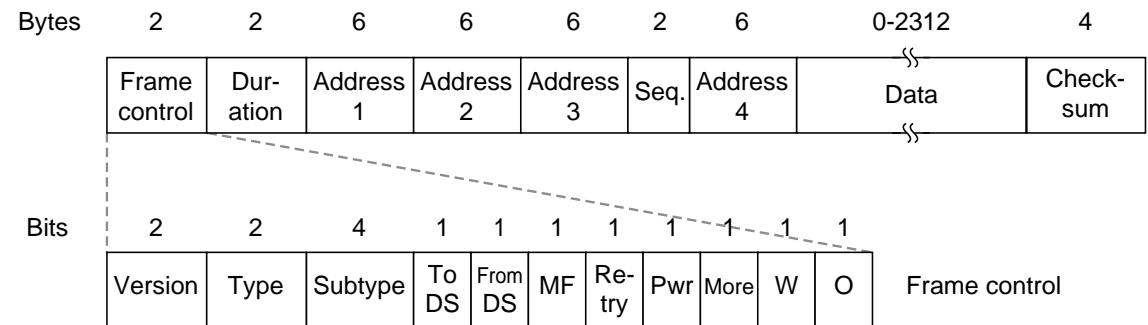
- **Duration**: tells how long frame and its ACK will occupy the channel

- **Address**: two addresses are for source and destination for inside cell traffic and the other two for source and destination for intercell traffic

- **Sequence**: allows fragments to be numbered, 12 bits identify frame and 4 bits identify fragment

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802.11 Services

- IEEE 802.11 standard requires each conformant wireless LAN must provide 9 services: five distributed services and four station services

- Distributed services: relate to managing cell membership and interacting with users outside cell
  - **Association**: used by mobiles to connect to base. When a mobile moves into a new cell, it announces its identity and capability. The base may then accept or reject it
  - **Disassociation**: mobile or base may disassociate. Mobile uses this service before shutting down or leaving, and base may also use it before going down for maintenance
  - **Reassociation**: mobile may use this service to change its preferred base station. This is useful e.g. when moving across cell boundary
  - **Distribution**: determines how to route frames sent to base. For local destination, frames can be sent out directly over air, otherwise, they have to be forward to wired network
  - **Integration**: translates from 802.11 format to non-802.11 format required by destination network

- Station services: related to activity within a single cell
  - **Authentication**: user must be authenticated before it is permitted to send data. After mobile is associated with a base, authentication process is carried out
  - **Deauthentication**: when a previous authenticated user wants to leave, it is deauthenticated
  - **Privacy**: manages encryption and decryption
  - **Data delivery**: provides means of transmitting and receiving data. 802.11 does not guarantee to be reliable, and higher layer must deal with error detection and correction

Summary

- FDDI, timed token ring, MAC protocol and frame structure, how it differs from 802.5 token ring

- Multiple access technique overview: FDMA or WDMA, TDMA, CDMA, SDMA

- WDMA LAN: how MAC protocol works

- Digital cellular network, GSM control channels and call set up

- Wireless LANs: hidden station and exposed station problems, multiple access with collision avoidance

- Wireless LANs IEEE 802.11 MAC protocol, frame structure and services

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