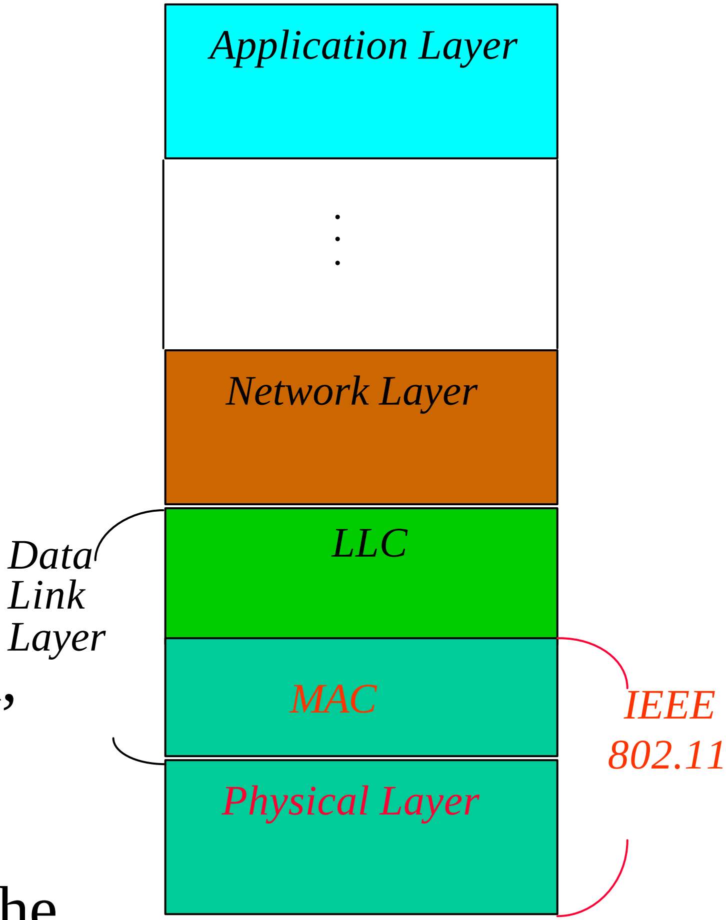
Wireless Local Area Network
(IEEE 802.11)

無線區域網路標準-IEEE 802.11

- Specifies a single Medium Access Control (MAC) sublayer and 3 Physical Layer Specifications.
- Stations can operate in two configurations :
  - Ad-hoc mode
  - Infrastructure mode
- Three PHY specifications
  - Frequency Hopping Spread Spectrum (FHSS).
  - Direct Sequence Spread Spectrum (DSSS).
  - Infrared PHY.

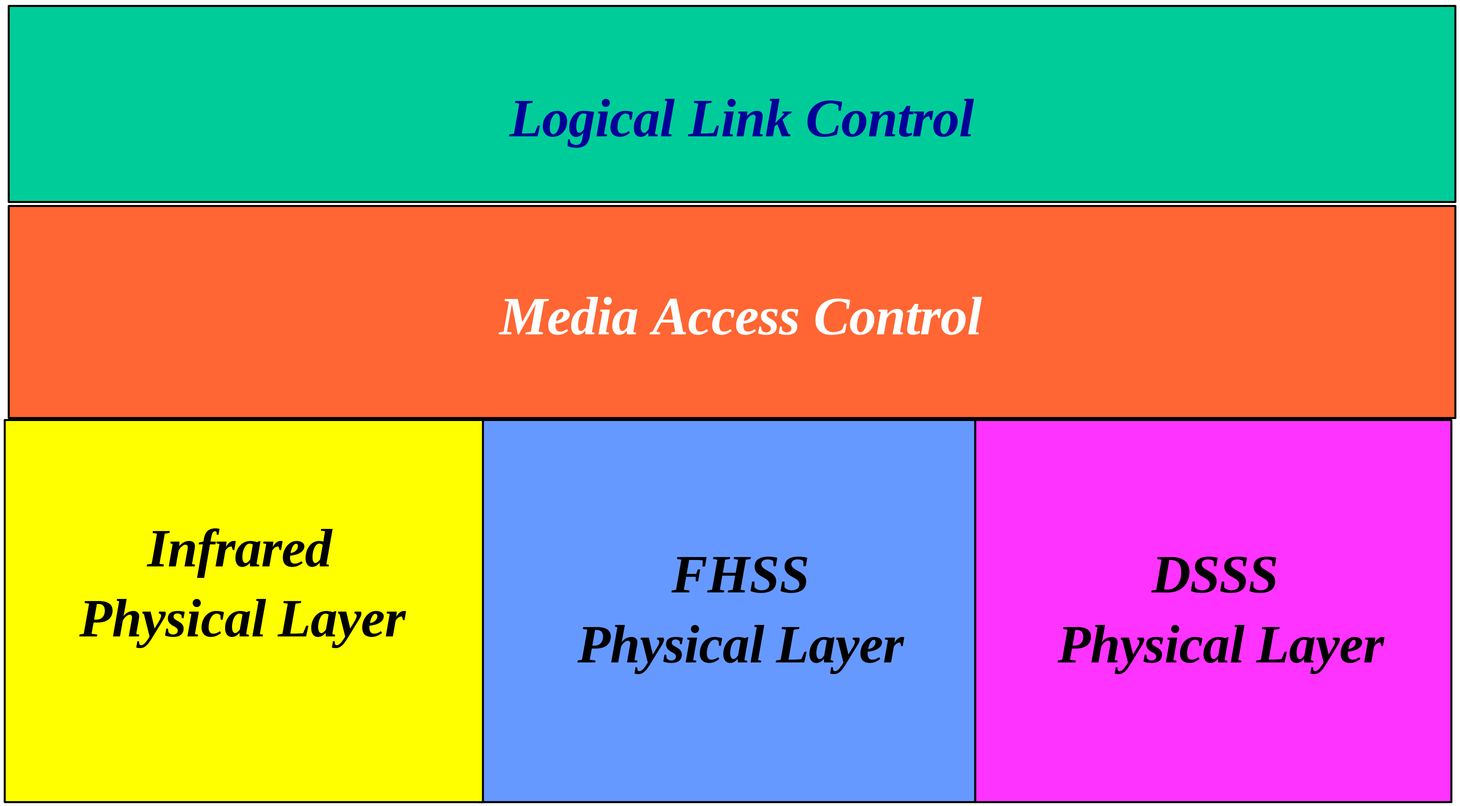
IEEE 802.11規範

- IEEE Project 802 Charter:
  - Local & Metropolitan Area Network
  - 1Mbps to 100Mbps and higher
  - 2 lower layers of 7 Layer OSI Reference Model
- IEEE 802.11 Working Group scope:
  - Wireless connectivity for fixed, portable and moving stations within a limited area
  - Appear to higher layer (LLC) the same as existing 802 standards



IEEE 802.11架構

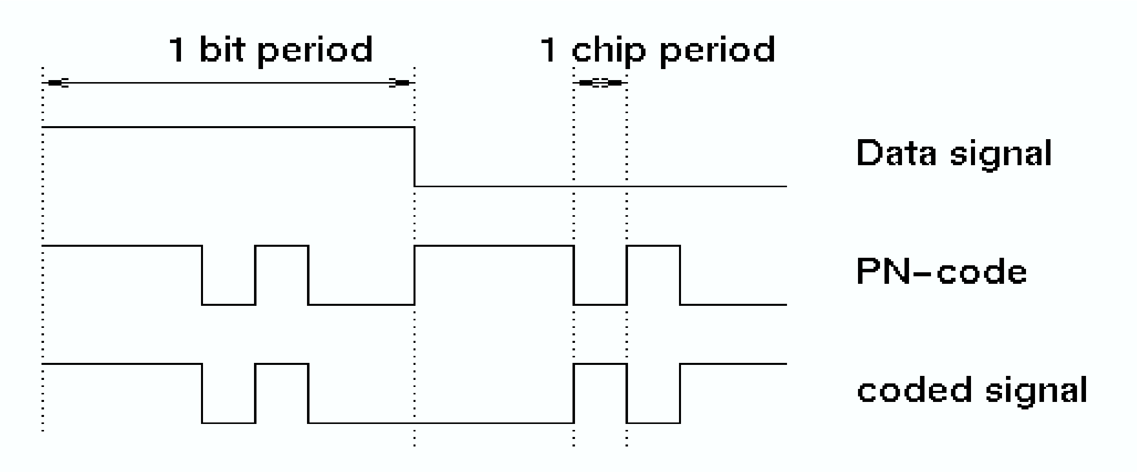
- 1997/6/26通過成為IEEE 802系列標準

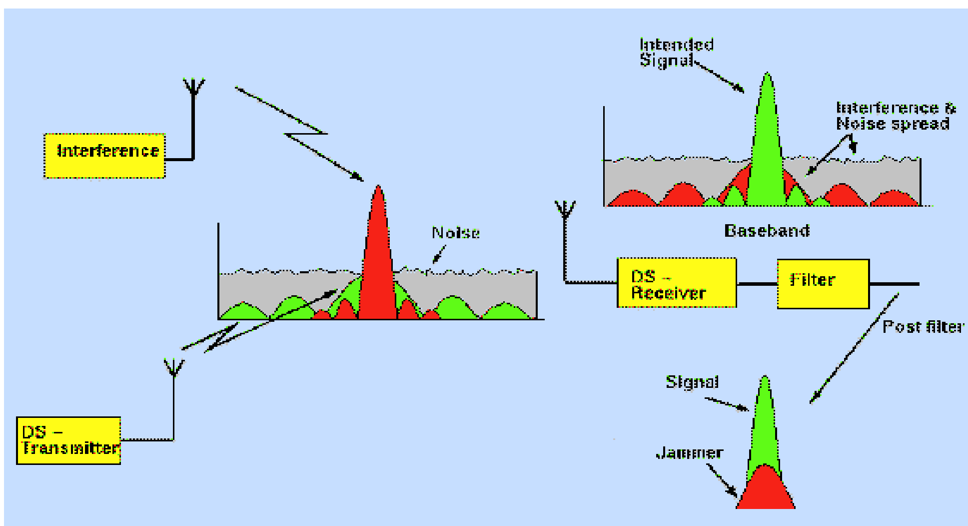


Spread Spectrum Technology

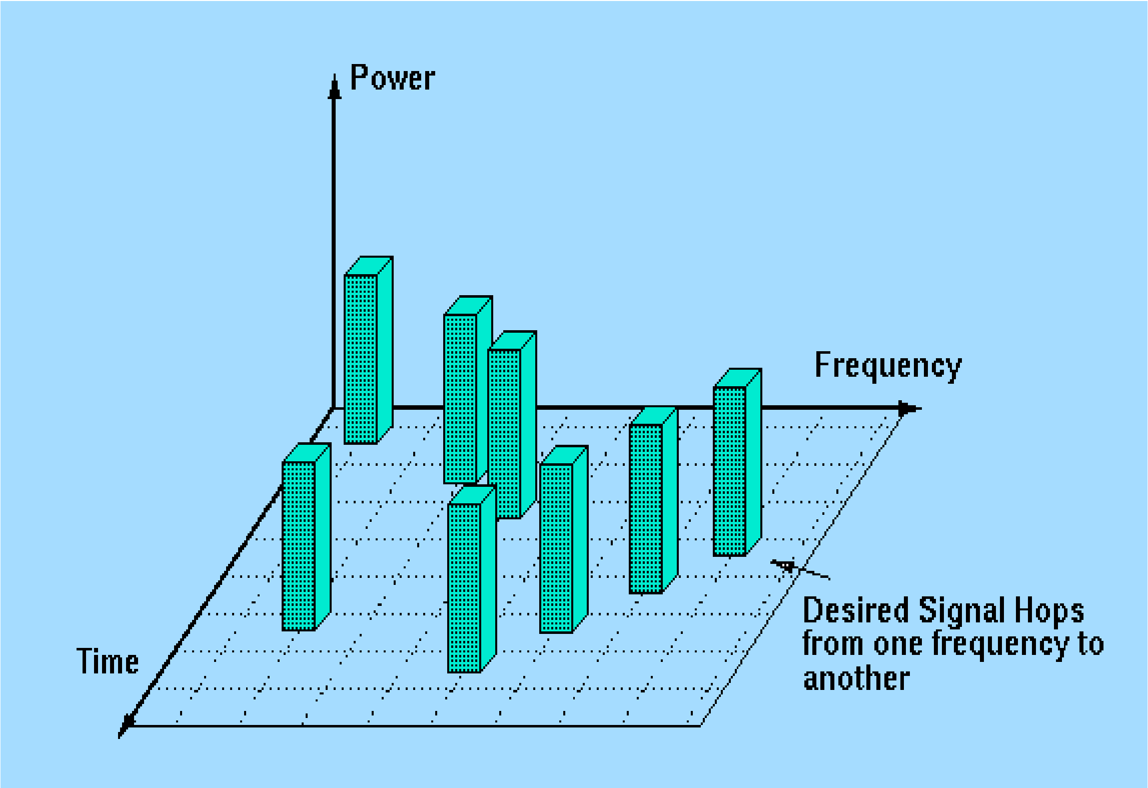
- IEEE 802.11：
  - DSSS（Direct Sequence Spread Spectrum）
    - 11channels
    - PN-code長度為11-bit
    - 展頻寬度為11MHz
  - FHSS（Frequency Hopping Spread Spectrum）
    - 78 hop sequences
    - 頻帶範圍為1MHz,
    - 跳頻的頻率為每秒2.5次
  - Infrared Ray
- **展頻技術的比較角度：**
  - **抗干擾能力**
  - **網路容量及可變度**
  - **系統傳輸績效**
  - **可移動性及安全性等。**
- **發展趨勢：**DHSS**往高速無線區域網路系統發展，適合辦公室環境使用；**FHSS**會往低價網路應用發展，提供**SOHO**及家庭應用、或周邊設備之無線網路連結。**

直接序列展頻（DSSS）

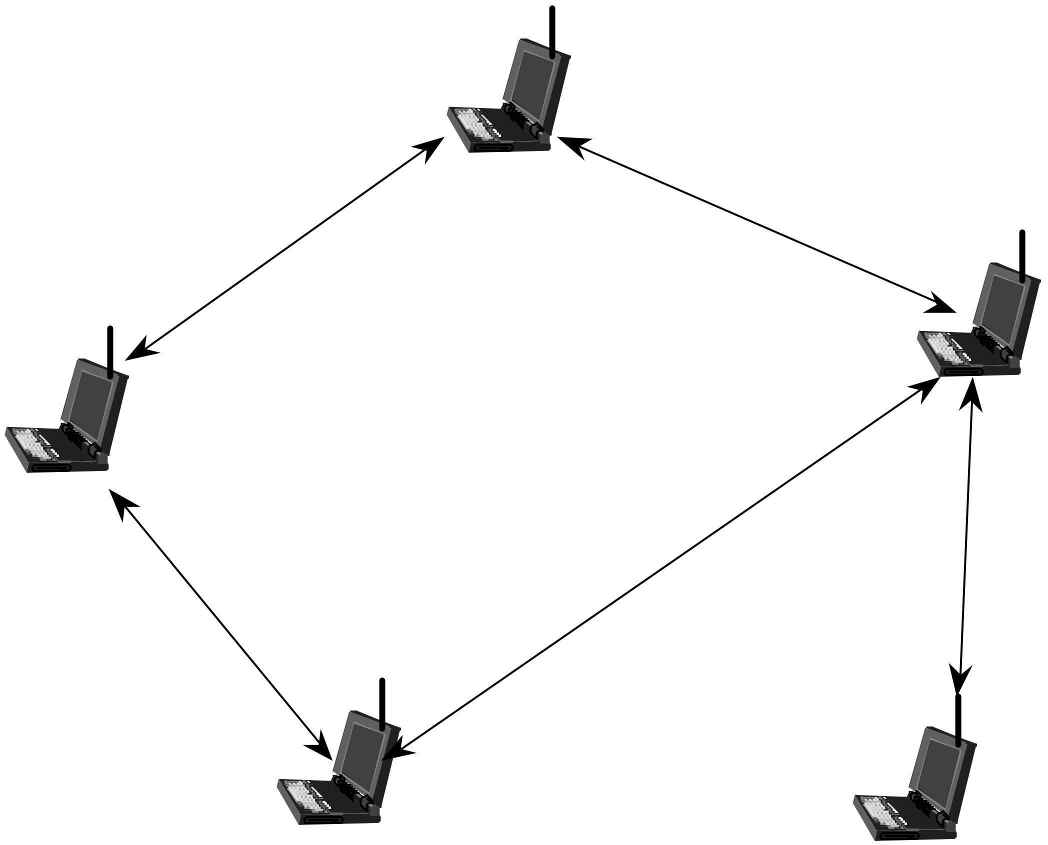

1 bit period
1 chip period
Data signal
PN-code
coded signal


Interference
Noise
DS - Transmitter
Intended Signal
Interference & Noise spread
Baseband
DS - Receiver
Filter
Post filter
Signal
Jammer

跳頻展頻（FHSS）

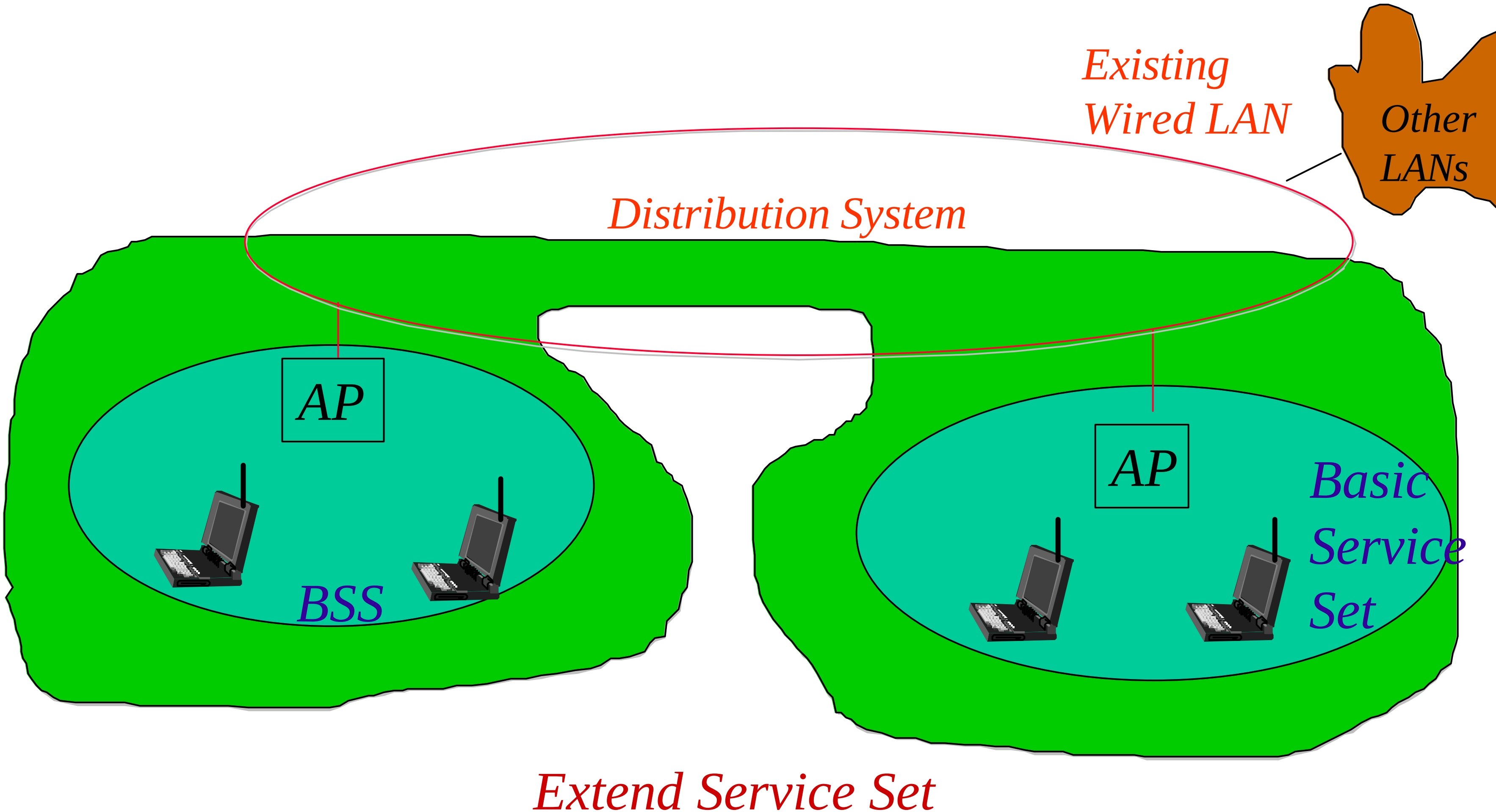

Power
Frequency
Time
Desired Signal Hops from one frequency to another

Ad Hoc網路



- One Basic Service Set
- Directed Connection
- Limited Coverage Area

Infrastructure網路



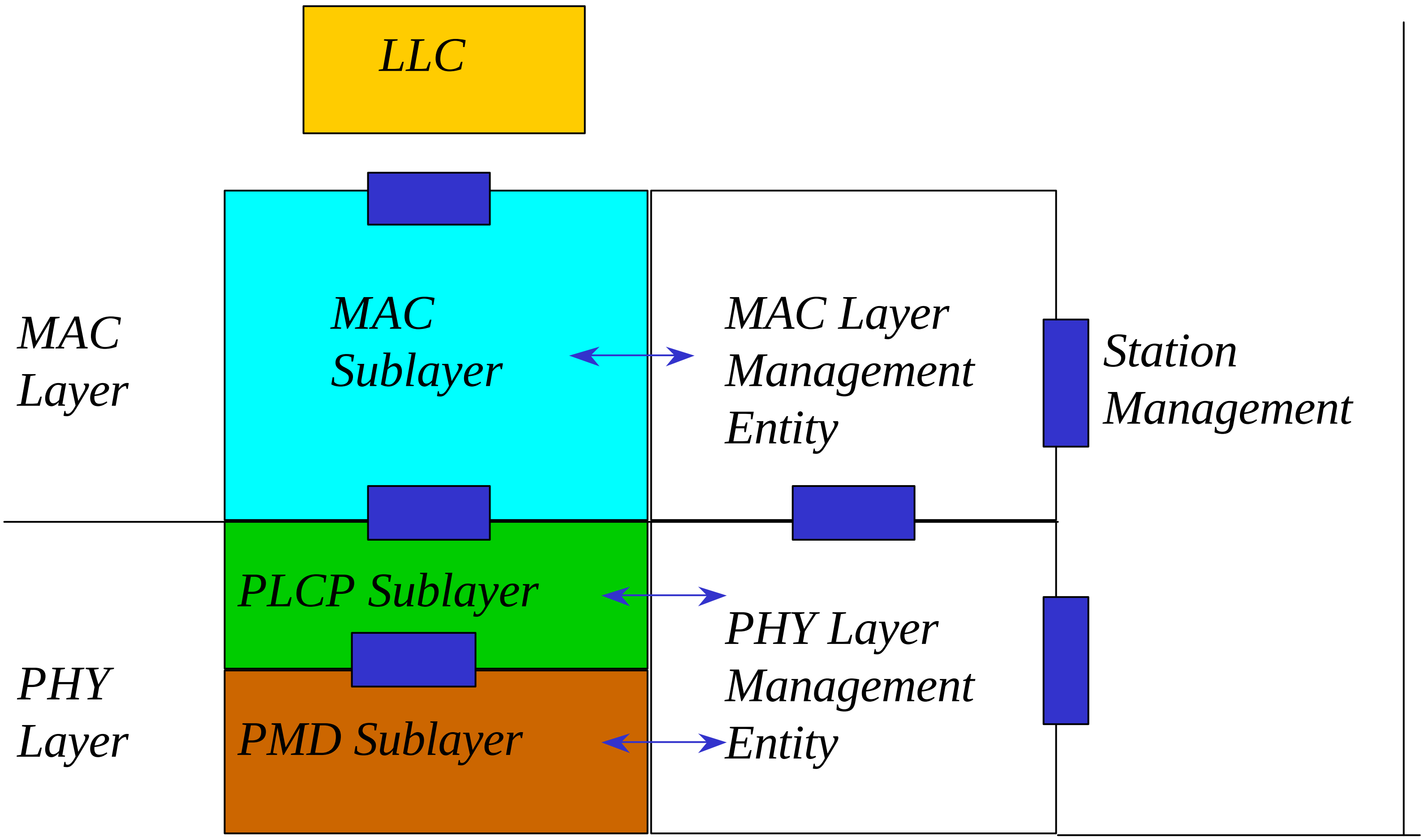
Infrastructure網路 (cont.)

- Access Point and Mobile Station
- Distributed System Interconnect Multiple Cells via Access Points to form a single network
- Extends Wireless Coverage Area
- Multiple Basic Service Sets connected together form ar Extended Service Set
- Allow Mobile Station to access fixed resource
- Support Roaming for Mobile Stations via Access Point
- Point Coordination Function, Power Management, Time Synchronization support through Access Point

IEEE 802.11 Services

- Provides services with the following functionality: roaming within a ESS, multiple data rates in BSSs and Power Management.
- The MAC protocol is Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- MAC services
  - Association service
  - Authentication service
  - Distribution service
  - Integration service
  - Deauthentication/Deassociation service

IEEE 802.11通訊協定層級



資料來源：IEEE

IEEE 802.11通訊協定功能

MAC Entity

- Basic access mechanism
- fragmentation
- Encryption

MAC Layer Management Entity

- Synchronous
- Power Management
- Association and Re-association
- Roaming (hand-off)
- MAC MIB

Physical Layer Convergence Protocol (PLCP)

- Support common PHY SAP
- Scramble / Descramble
- Provides Clear Channel Assessment Signal

Physical Medium Dependence Sublayer (PMD)

- Modulation and Encoding
- 2.4 GHz ISM or Infrared Ray

PHY Layer Management Entity

- Channel tuning
- Maintaining PHY MIB

Station Management

- Interacts with both MAC Management and PHY Management

IEEE 802.11 TGa

- The TGa is working on the high data-rate extension in the 5 GHz band, project 802.11a, was able to produce a new draft standard that has the support of at least 80 % of the members.
- TGa is looking at a candidate for worldwide standardization!

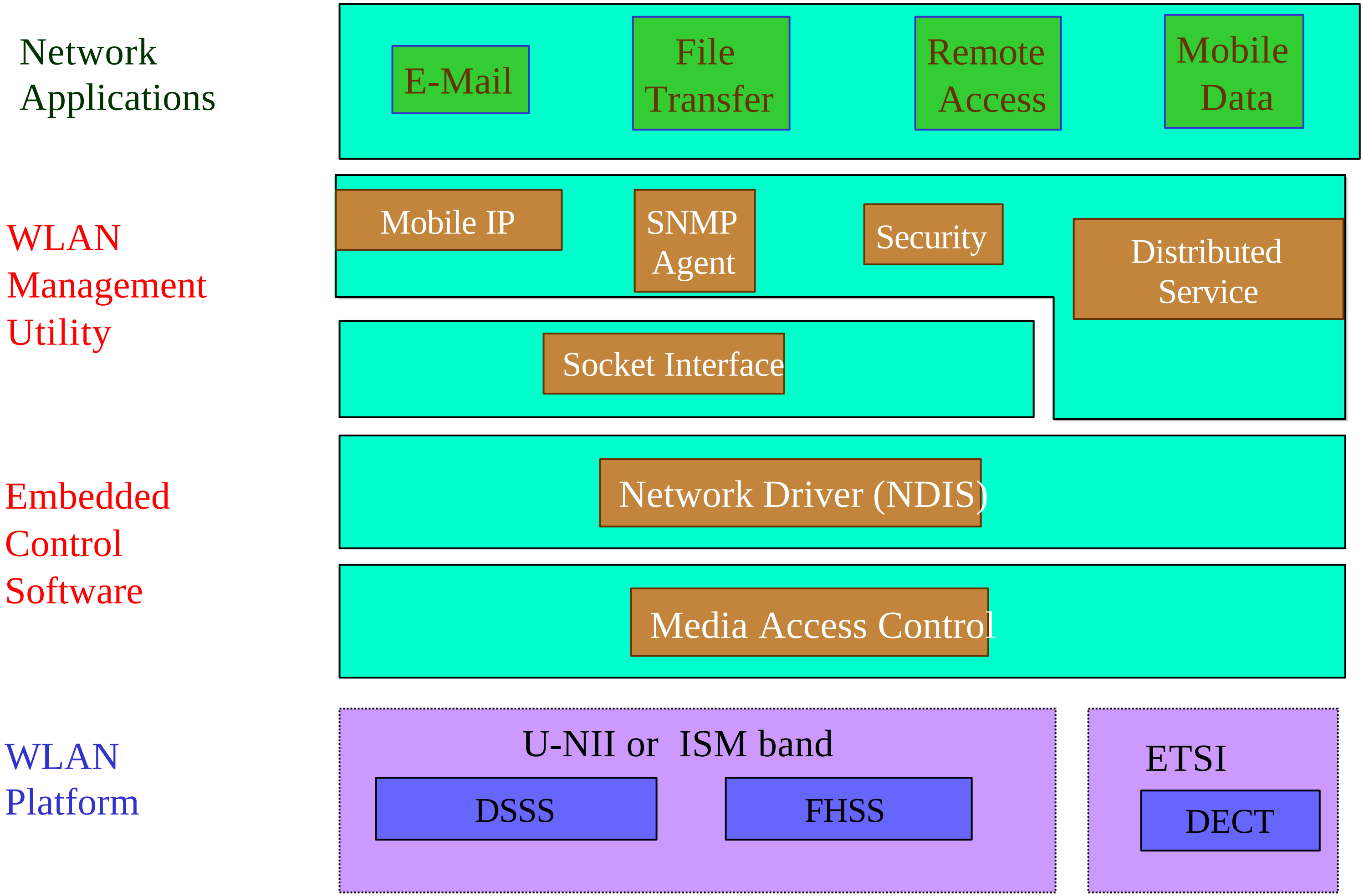
IEEE 802.11 TGa (cont.)

- The specifications of the Physical Layer encompass data rates from 6 Mbit/s up to 54 Mbit/s, with 20 MHz spacing between adjacent channels.
- All implementations are required to support 6, 12 and 24 Mbit/s. Optional extensions are for 9, 18, 36, 48 and 54Mbit/s.
- The multi-rate mechanism of the MAC protocol ensures that all devices communicate with each other at the best data rate in the present channel.

IEEE 802.11 TGb

- The TGb is working on the extension of the 1 and 2 Mbit/s data rates in the 2.45 GHz band with 5.5 and 11 Mbit/s has reached a technical compromise solution to improve the co-existence and interoperability characteristics between options.
- The multi-rate mechanism warrants that the 11 Mbit/s operation can switch back to 5.5Mbit/s. Stations that are even further could switch back to the 2 and 1 Mbit/s capabilities of the DSSS modulation.

無線區域網路軟體技術架構



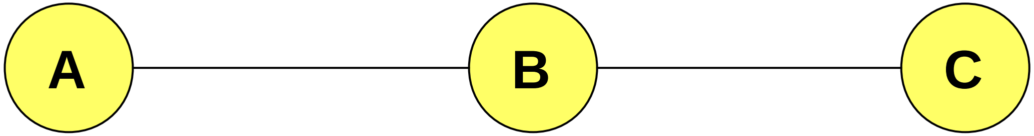
MAC Protocols: Issues

- Hidden Terminal Problem
- Reliability
- Collision avoidance
- Congestion control
- Fairness
- Energy efficiency

Hidden Terminal Problem

- Node B can communicate with A and C both
- A and C cannot hear each other

- When A transmits to B, C cannot detect the transmission using the *carrier sense* mechanism
- If C transmits, collision will occur at node B



MACA Solution for Hidden Terminal Problem [Karn90]

- When node A wants to send a packet to node B, node A first sends a *Request-to-Send (RTS)* to A

- On receiving RTS, node A responds by sending *Clear-to-Send (CTS),* provided node A is able to receive the packet

- When a node (such as C) overhears a CTS, it keeps quiet for the duration of the transfer
  - Transfer duration is included in RTS and CTS both

Reliability

- Wireless links are prone to errors. High packet loss rate detrimental to transport-layer performance.
- Mechanisms needed to reduce packet loss rate experienced by upper layers

A Simple Solution to Improve Reliability

- When node B receives a data packet from node A, node B sends an Acknowledgement (Ack). This approach adopted in many protocols [Bharghavan94,IEEE 802.11]

- If node A fails to receive an Ack, it will retransmit the packet

IEEE 802.11 Wireless MAC

- Distributed and centralized MAC components
  - Distributed Coordination Function (DCF)
  - Point Coordination Function (PCF)
- DCF suitable for multi-hop ad hoc networking

IEEE 802.11 DCF

- Uses RTS-CTS exchange to avoid hidden terminal problem
  - Any node overhearing a CTS cannot transmit for the duration of the transfer
- Uses ACK to achieve reliability
- Any node receiving the RTS cannot transmit for the duration of the transfer
  - To prevent collision with ACK when it arrives at the sender
  - When B is sending data to C, node A will keep quite

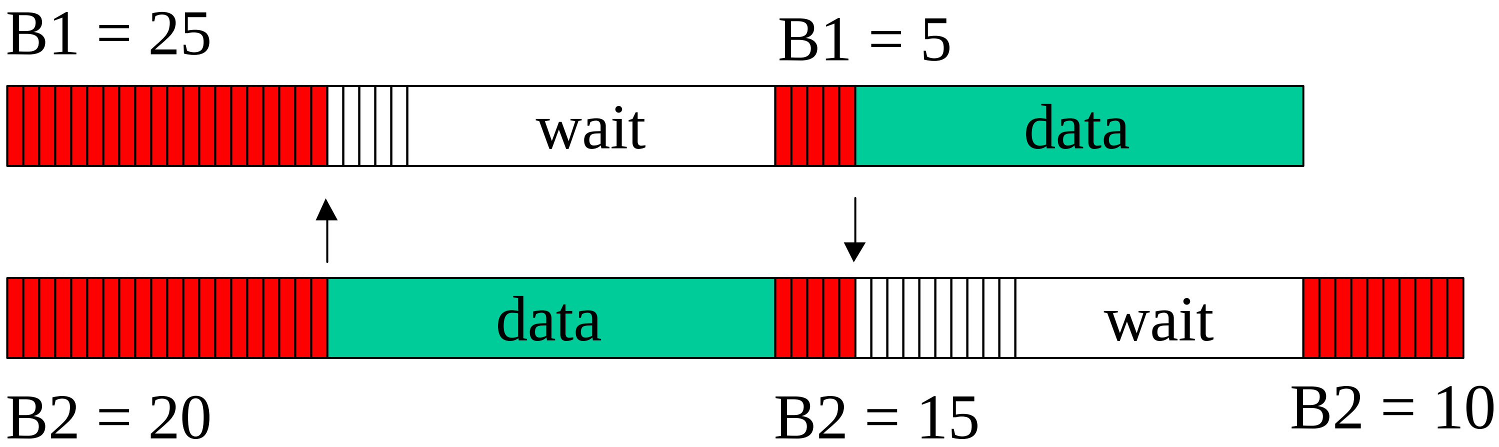
Collision Avoidance

- With half-duplex radios, collision detection is not possible
- **CSMA/CA:** Wireless MAC protocols often use *collision avoidance* techniques, in conjunction with a (physical or virtual) *carrier sense* mechanism
- Carrier sense: When a node wishes to transmit a packet, it first waits until the channel is idle
- Collision avoidance: Once channel becomes idle, the node waits for a randomly chosen duration before attempting to transmit

Congestion Avoidance: IEEE 802.1 DCF

- When transmitting a packet, choose a backoff interval in the range [0,cw]
  - cw is contention window
- Count down the backoff interval when medium is idle
  - Count-down is suspended if medium becomes busy
- When backoff interval reaches 0, transmit RTS

DCF Example



cw = 31

B1 and B2 are backoff intervals at nodes 1 and 2

Congestion Avoidance

- The time spent counting down backoff intervals is a part of MAC overhead
- Choosing a *large cw* leads to large backoff intervals and can result in larger overhead
- Choosing a *small cw* leads to a larger number of collisions (when two nodes count down to 0 simultaneously)

MAC Protocols: Issues

- Hidden Terminal Problem
- Reliability
- Collision avoidance
- Congestion control
- Fairness
- Energy efficiency

Congestion Control

- Since the number of nodes attempting to transmit simultaneously may change with time, some mechanism to manage congestion is needed

- IEEE 802.11 DCF: Congestion control achieved by dynamically choosing the contention window *cw*

Binary Exponential Backoff in DCF

- When a node fails to receive CTS in response to its RTS, it increases the contention window
  - *cw* is doubled (up to an upper bound)

- When a node successfully completes a data transfer, it restores *cw* to CW_{min}

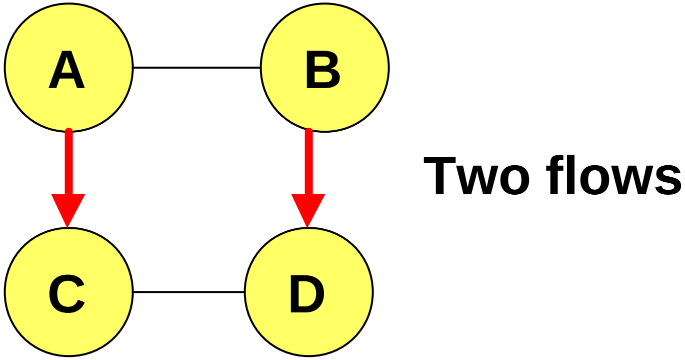
MILD Algorithm in MACAW [Bharghavan94Sigcomm]

- When a node fails to receive CTS in response to its RTS, it multiplies *cw* by 1.5
  - Similar to 802.11, except that 802.11 multiplies by 2
- When a node successfully completes a transfer, it reduces *cw* by 1
  - Different from 802.11 where cw is restored to Cw_{min}
  - In 802.11, cw reduces much faster than it increases
  - MACAW: cw reduces slower than it increases

    Exponential Increase Linear Decrease
- MACAW can avoid wild oscillations of cw when congestion is high

Fairness Issue

- Many definitions of fairness plausible
- Simplest definition: All nodes should receive *equal* bandwidth



Fairness Issue

- Assume that initially, A and B both choose a backoff interval in range [0,31] but their RTSs collide

- Nodes A and B then choose from range [0,63]
  - Node A chooses 4 slots and B choose 60 slots
  - After A transmits a packet, it next chooses from range [0,31]
  - It is possible that A may transmit several packets before B transmits its first packet

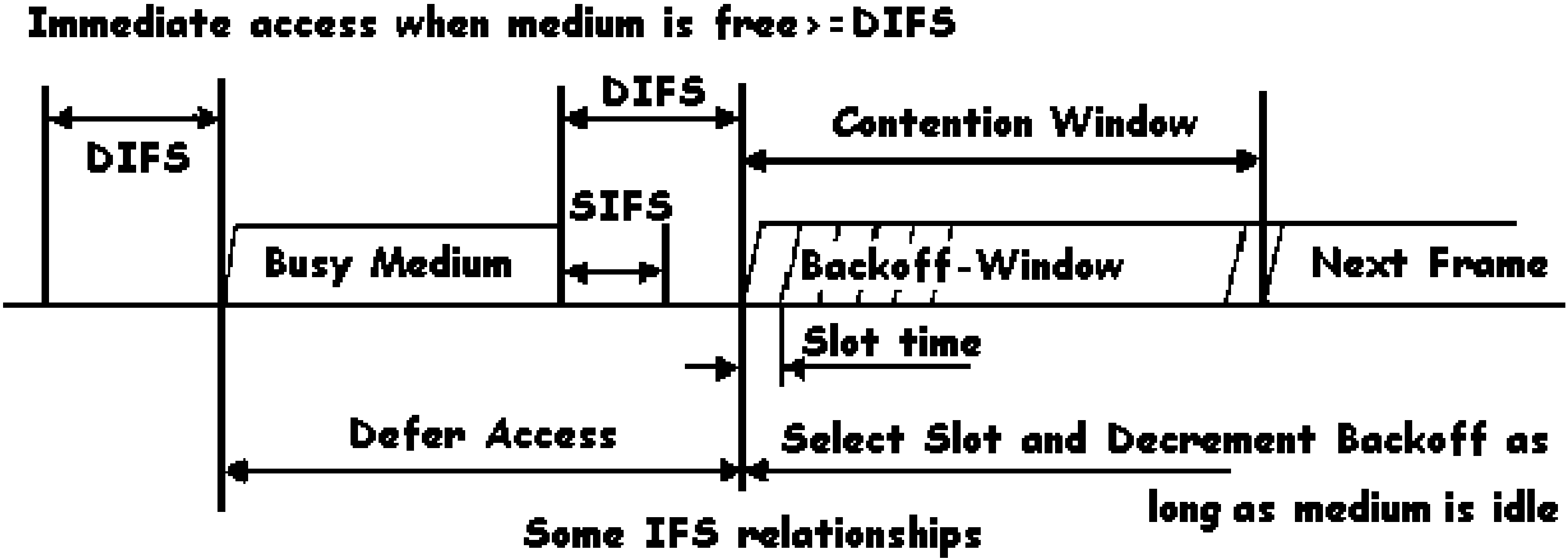
Fairness Issue

- Unfairness occurs when one node has backed off much more than some other node

MACAW Solution for Fairness

- When a node transmits a packet, it appends the *cw* value to the packet, all nodes hearing that *cw* value use it for their future transmission attempts
- Since *cw* is an indication of the level of congestion in the vicinity of a specific receiver node, MACAW proposes maintaining *cw* independently for each receiver
- Using per-receiver *cw* is particularly useful in multi-hop environments, since congestion level at different receivers can be very different

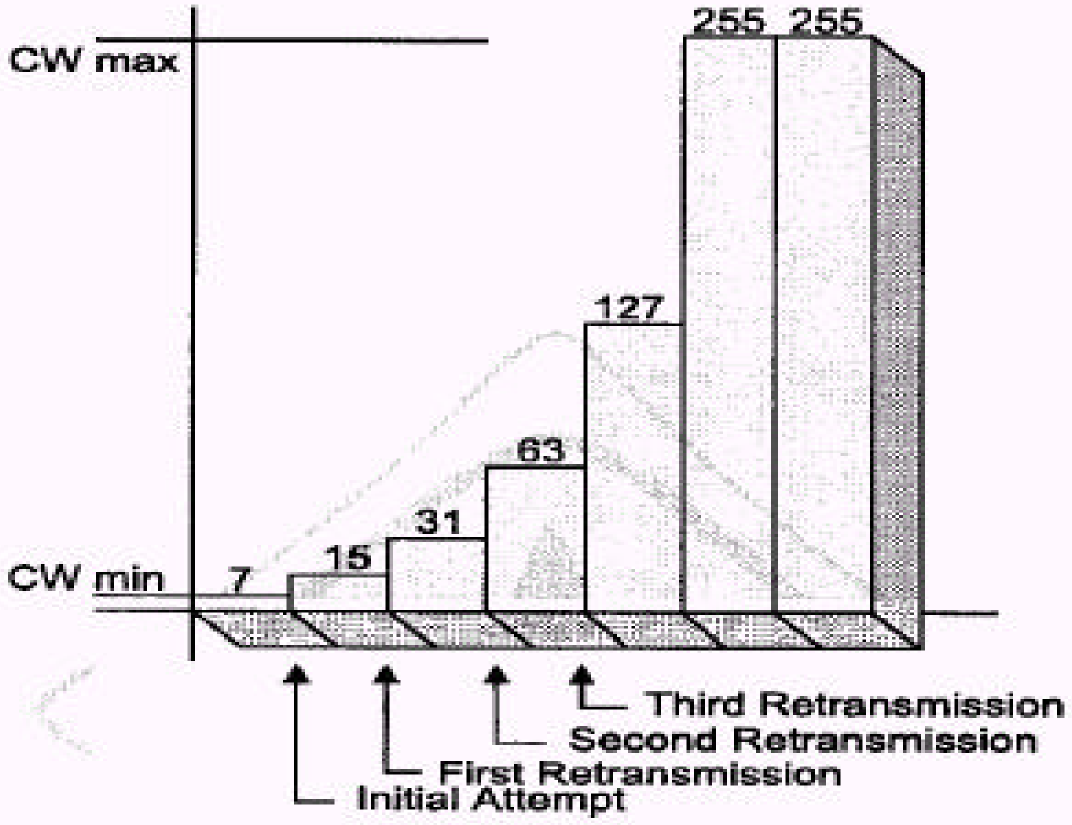
Some IFS relationships and basic access method



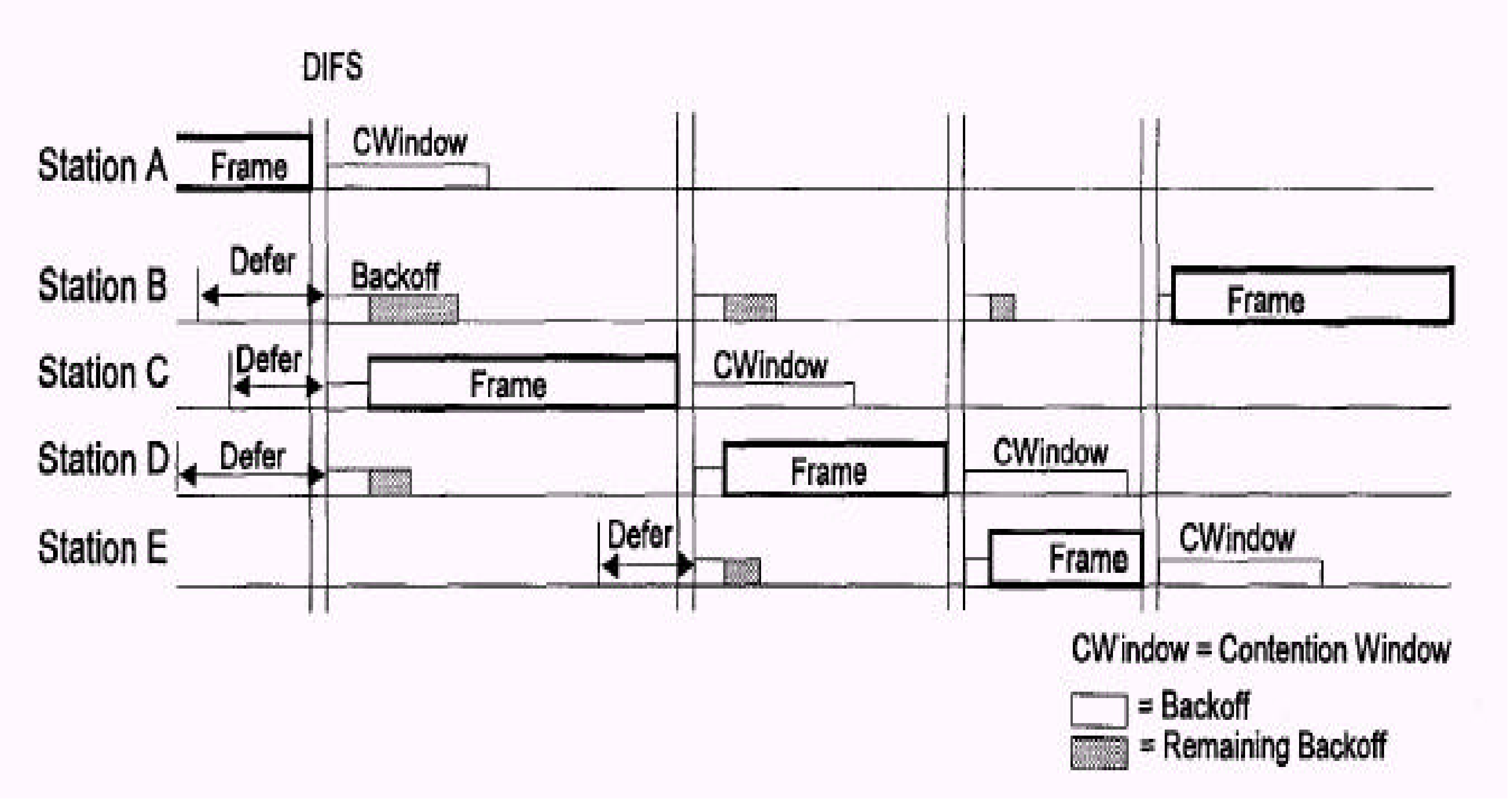
Random backoff time

- Backoff time = INT(CW * Random())*aSlotTime
- INT(x) : 小於或等於x的最大整數
- CW(contention window parameter) : 介於CWmin和Cwmax間的整數 , CW依序遞增的順序為(7,15,31,63,127,255,255,255……)
- Random() : 介於0到1間的實數
- aSlotTime : 傳送器開啟延遲 + 媒介傳遞延遲 + 媒介忙碌偵測反應時間

An example of exponential increase of CW



Backoff procedure



RTS/CTS/data/ACK and NAV setting