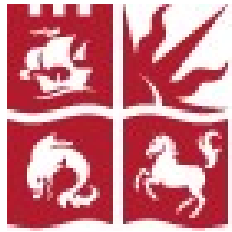
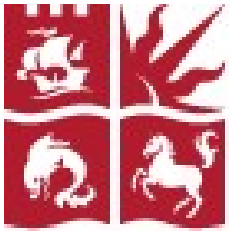


EENGM4221: Broadband Wireless Communications

Lecture 13: 802.11 Collision Avoidance, NAV and 2-Way Handshaking and the PCF protocol

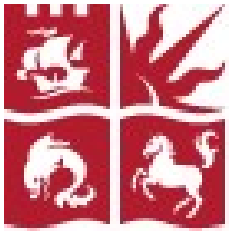
Dr Simon Armour

DCF MAC – Collision Avoidance



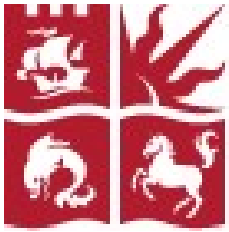
- In order to make collisions unlikely, each node must generate a random integer before accessing the medium
- Once the medium becomes free, the node must wait for a period of time determined by this random number
- This time is termed the contention window and is equal to the random number multiplied by a ‘slot time’
  - The slot time is a constant for any given 802.11 PHY but may vary between PHYs
  - Usually of the order of μs

DCF MAC – Function of the Contention Window (1)

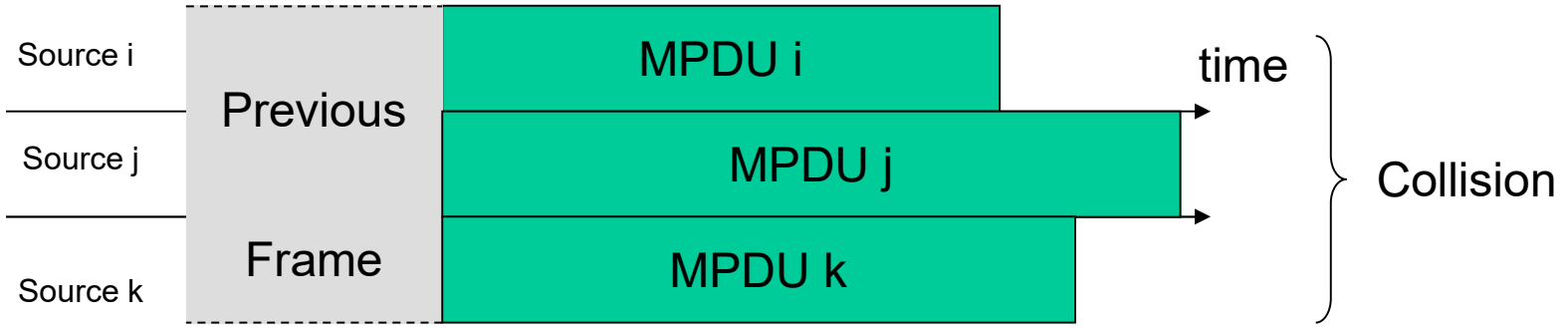


- Provided that no two nodes both choose the lowest number of all those chosen, collision is prevented
- The node which chooses the lowest number wins the contention and starts transmission when its CW ends
- By the time the CWs of the other nodes end, the medium is no longer free and they thus must defer to the transmission of the node they lost contention to.

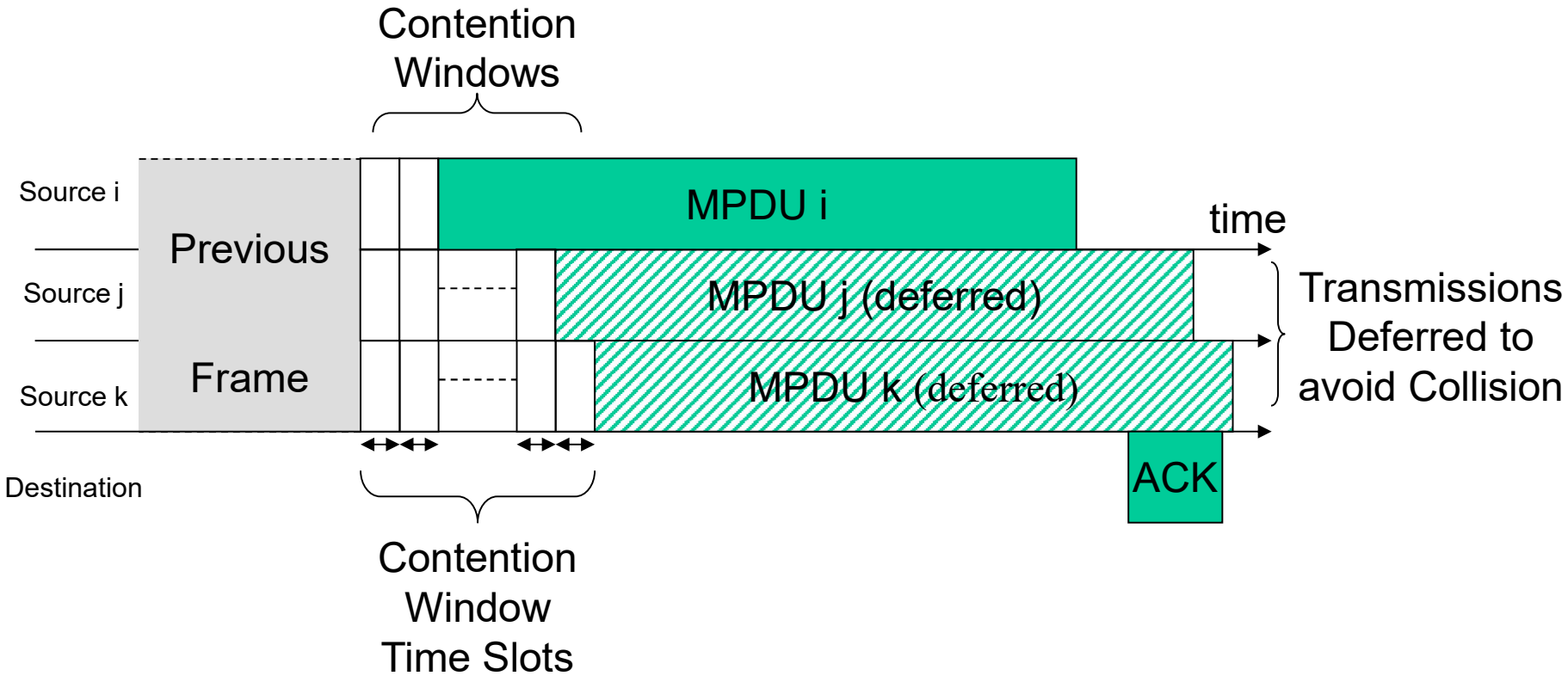
DCF MAC – The Collision Problem



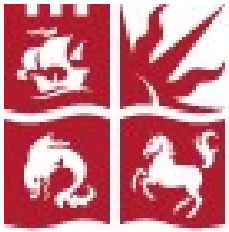
- What happens if many nodes all want to transmit?
- They all have to sense the medium and then wait until it becomes free (i.e. the previous transmission finishes)
- If more than one node is waiting, they will all attempt transmission when the previous transmission finishes
- A collision is certain whenever any two nodes are waiting for the medium
  - This is quite a common occurrence if the network is loaded to anywhere near its capacity and load is well spread between nodes



DCF MAC – Function of the Contention Window (2)

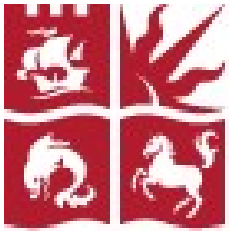


DCF MAC – Binary Exponential Backoff



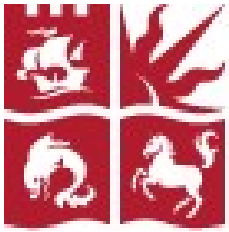
- There is still a chance that two nodes will 'win' the contention by generating the same (equal smallest) number
- The probability of this is inversely related to the range of numbers in the random set. A bigger number:
  - Minimises collision probability
  - Adds more dead time (on average) when no data is being sent
- Ideally, the CW range is scaled according to the number of nodes contending
- This is done via a Binary Exponential Backoff
  - The range is initially set to $0 \rightarrow 2^3-1$, i.e. $0 \rightarrow 7$
  - Each time a collision is detected, the exponent is increased by 1 to give the series: $0 \rightarrow 7$, $0 \rightarrow 15$, $0 \rightarrow 31$, $0 \rightarrow 63$, $0 \rightarrow 127$, $0 \rightarrow 255$, $0 \rightarrow 511$, $0 \rightarrow 1023$
  - Each time a packet is successfully transmitted, the range resets to $0 \rightarrow 7$
  - $0 \rightarrow 1023$ is the maximum CW range. This ensures low collision probability even for networks with many nodes. Dead time (overhead) should not be too big since one node should normally generate a low CW length and thereby win contention

Inter Frame Spaces

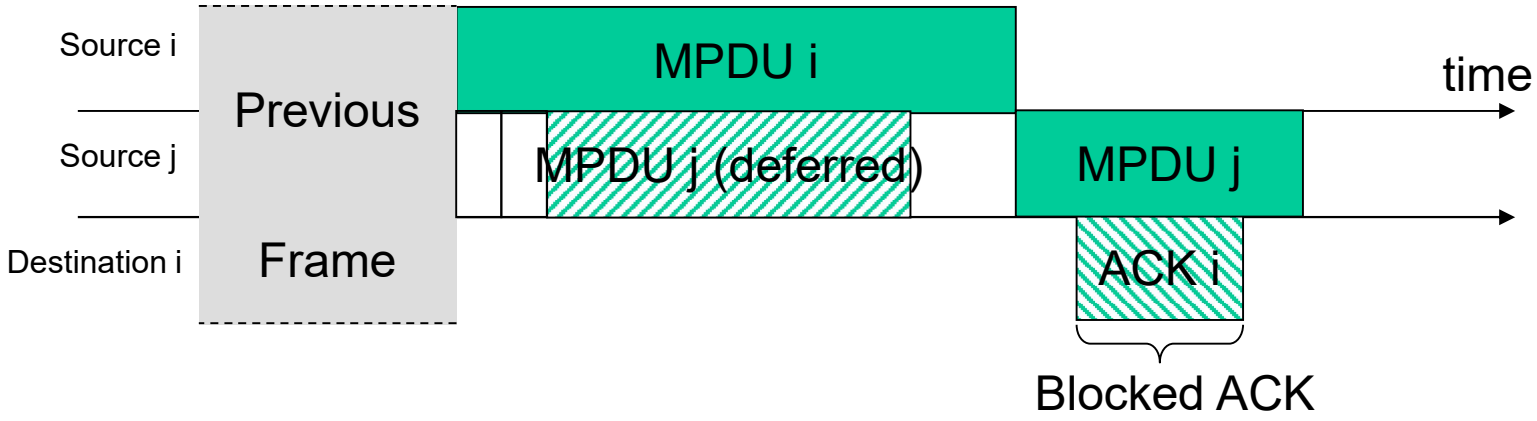


- To facilitate MAC functionality, 802.11 enforces certain Inter Frame Spaces (IFS)
  - IFSs are simply silent periods between frames on the medium
  - Every frame transmitted on the medium must be preceded by an IFS
  - The right to use a shorter IFS gives one frame priority over another
  - Since no data is transmitted during the IFS it represents an overhead.
    - More IFS time results in a less efficient MAC

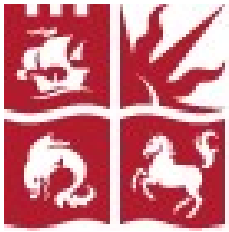
DCF – SIFS and DIFS (1)



- Note that in previous diagrams, there is a non-zero time gap between the end of a data frame and the start of a corresponding ACK frame
- This is required in order to allow the destination frame to perform error checking and generate an appropriate ACK message
- There is the potential for another node to initiate transmission of its own data frame before the destination node is able to generate the ACK



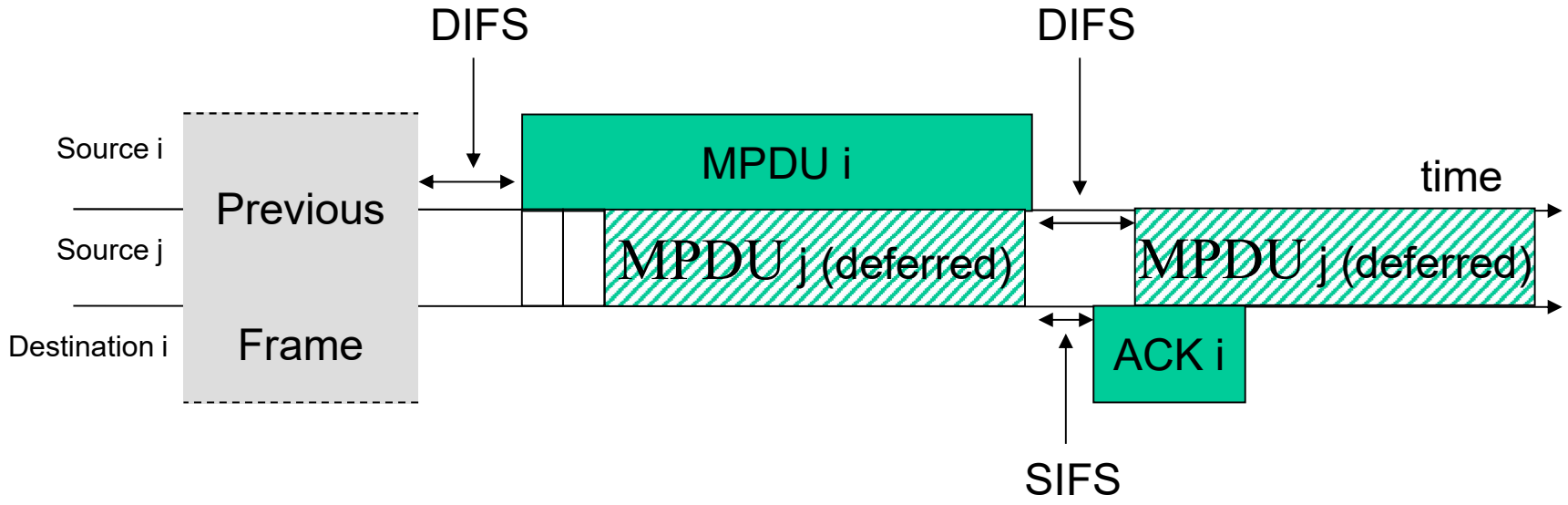
DCF – SIFS and DIFS (2)



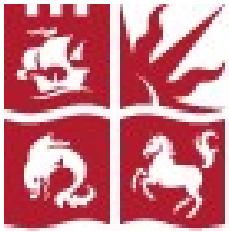
- In order to prevent this, two IFS definitions are required:
  - The IFS between a data frame and a corresponding ACK frame is fixed in length and described as the Short IFS (SIFS)
  - A further requirement for an IFS before the beginning of the CW is added. This is termed the Distributed IFS (DIFS)

DCF – SIFS and DIFS (3)

- Together, these IFS ensure that a new data frame can never begin between a previous data frame and corresponding ACK since, no matter what random CW is generated (even 0), the new data frame will always have to wait longer than SIFS before it can start – by which time the destination node for the previous transmission will have started to transmit the ACK and the medium will no longer be free; all other nodes will be forced to defer according to CSMA and won't get the chance to decrement their CWs

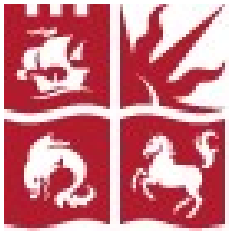


The NAV – Logical Carrier Sensing

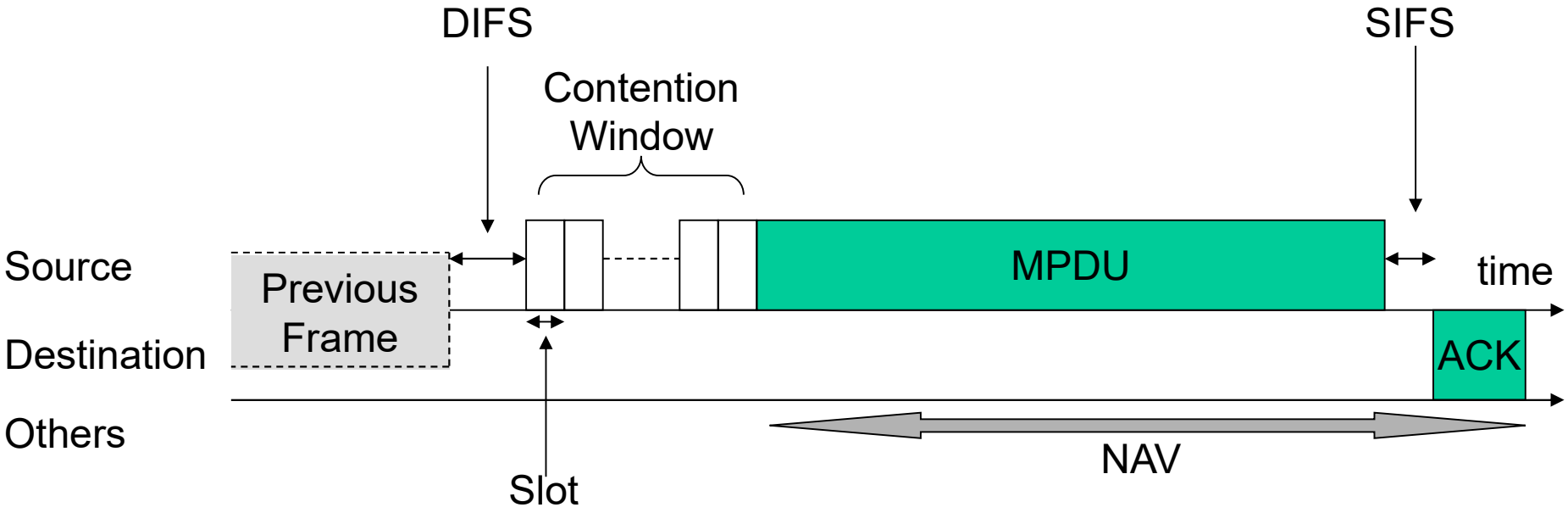


- DCF actually implements Carrier Sensing in two ways
  - One is the physical sensing of the medium
  - The other is logical carrier sensing
    - This is achieved by receiving the header of frames transmitted by other nodes
    - Since this header contains information on the size, modulation and coding of the frame, any node can deduce the time that this frame (and corresponding subsequent parts of the frame exchange sequence such as SIFS and ACK) will take
    - Having determined this time, a node sets a Network Allocation Vector (NAV)
    - The NAV is how long the node knows the channel will be busy for
    - There is no point in Physically sensing the medium again until the NAV expires
    - Nodes can save power by not sensing the medium unnecessarily

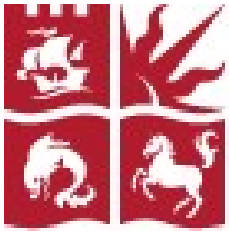
DCF – 2-way handshaking protocol



- Considering the CSMA, explicit ACK, CW and IFS requirements, a standard frame exchange under DCF is often illustrated as below
- It is described as a two way handshake since 2 frames are transmitted over the medium – Data and ACK

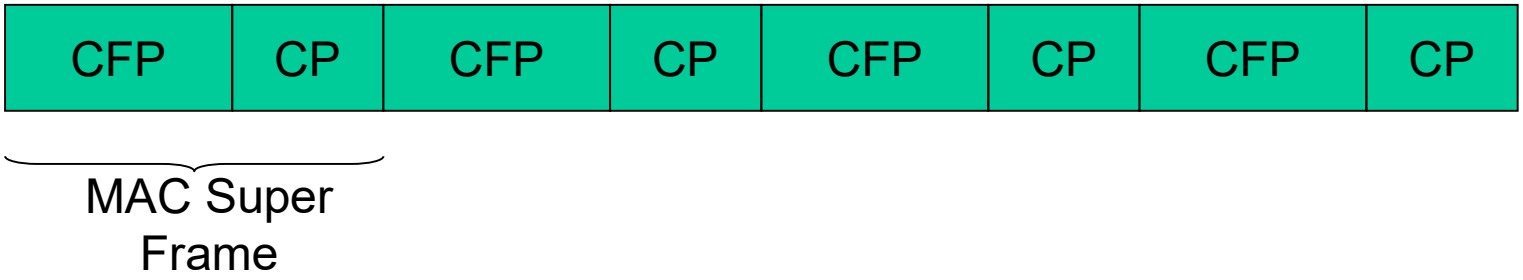


PCF (1)



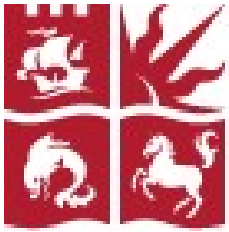
- The Point Coordination Function is included as an option in 802.11
  - It allows a Point Controller (probably an Access Point) to take control of the medium since it is only has to wait a PIFS rather than a DIFS before transmitting.
  - Point Control is synonymous with Central Control
    - An Infrastructure is implied by the existence of a PC
  - The PC can poll stations to ask if they have any data to send or to tell them that they may transmit their data. It can also transmit its own data to them
  - Together these capabilities enable the PC to gather information as to which nodes have data to transmit and to subsequently schedule access to the medium and dictate this schedule to the other nodes
  - A good scheduler could take account of QoS requirements and schedule accordingly
- In order to support non-PCF capable nodes, a portion of time in which DCF applies must be retained. Time is divided up into Contention Free (Scheduled) and Contention (DCF controlled) phases.

PCF (2)



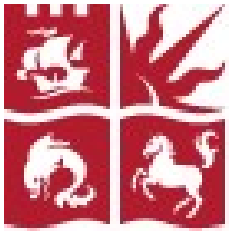
- The PC is free to choose the length of the CFP and CP but must allow some time in the CP for non-PCF compliant devices
- In reality the PCF has some fundamental flaws (including the ability of a node to win contention at the end of one CP and continue to transmit into the following CFP, thereby crippling the schedule planned by the PC)
- Partly because of these flaws and partly to save development costs the PCF has been almost completely ignored for commercial products

PIFS and EIFS



- SIFS and DIFS have already been explained
- Recall that the right to use a shorter IFS constitutes priority in terms of access to the medium
- Two further IFS exist
  - The PCF IFS (PIFS) is the time a point co-ordinator (Central Controller) must wait before taking control of the medium.
  - The EIFS is the longest IFS and is chosen to be longer than the longest possible valid frame exchange sequence. Nodes which 'lose track' of the ongoing frame exchange are forced to wait for an EIFS before attempting to access the medium again in order to prevent them interrupting any current frame exchange sequence (2-way or 4-way)

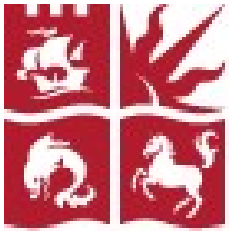
IFS durations



- PIFS should be shorter than DIFS but longer than SIFS. This gives the point co-ordinator priority over the other nodes but prevents it taking control of the medium mid way through a frame exchange (2-way or 4-way)
  - This stops it wasting resource by interrupting a frame exchange which might otherwise have succeeded

- Thus: $T_{SIFS}<T_{PIFS}<T_{DIFS}<T_{EIFS}$

Review of Lecture 13



- We have identified further enhancements to the basics of CSMA and explicit ACKs
  - Collision Avoidance and the BEB algorithm that adapts it
  - Inter Frame Spaces to provide priority between different packet types
  - Logical Carrier sensing; a way to save energy
- Combining CSMA, explicit ACKs, Collision Avoidance, Inter Frame Spaces and Logical Carrier sensing, we have achieved the MAC protocol most often used in 802.11 WiFi Networks: 2-way handshaking DCF
- We briefly discussed PCF, a niche alternative to DCF

Ref: