Quality of Service Enhancement in IEEE 802.11e

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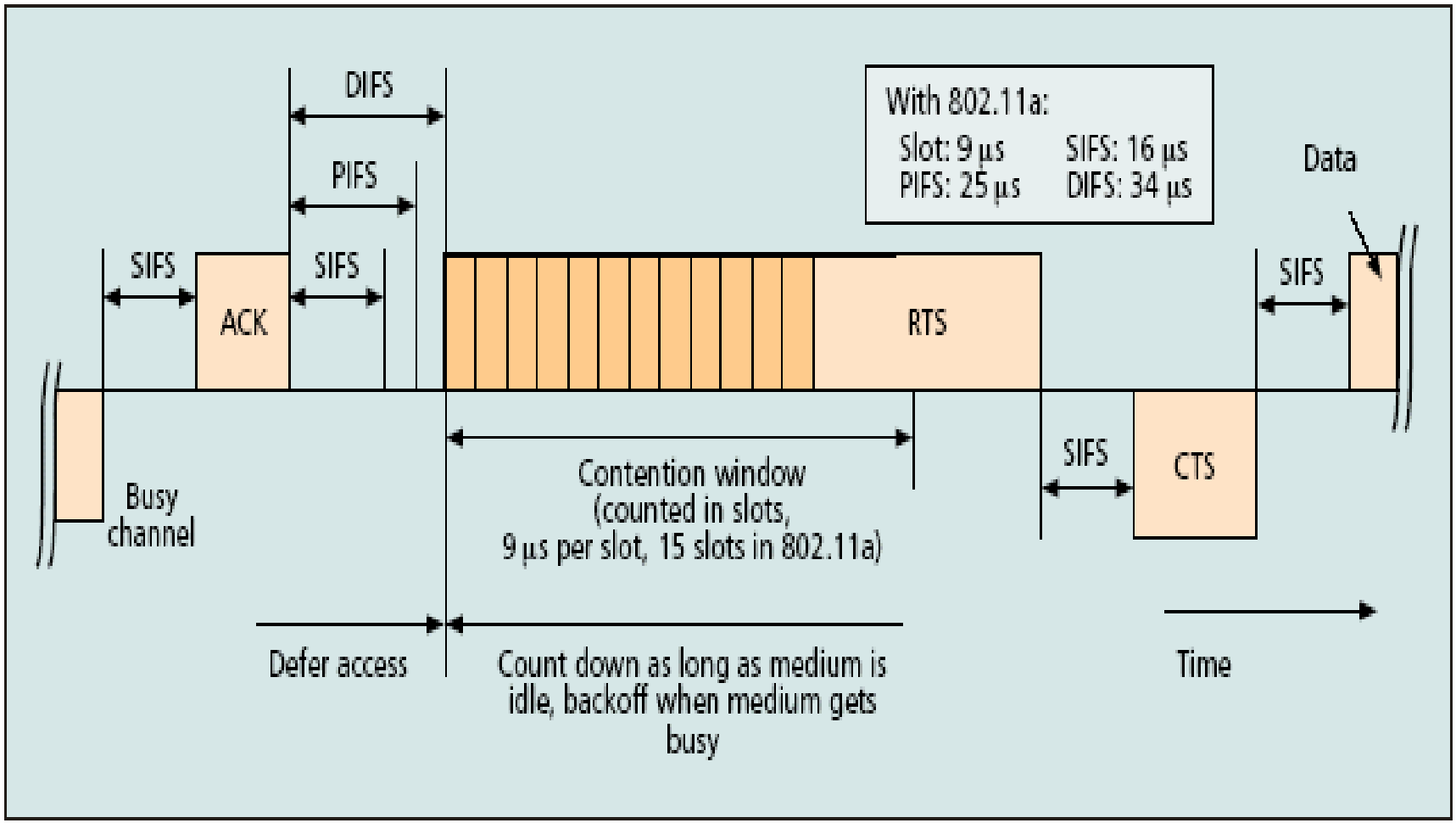
Part I: A Brief Background on IEEE 802.11 MAC (original)

- DCF (*Distributed Cooperation Function*): listen before talk scheme

- Based on CSMA/CA (*Carrier Sense Multiple Access)/Collision Avoidance*)

- CSMA/CA mechanism to reduce the probability of collisions : after detecting the medium as idle for a minimum duration called DCF interframe space (DIFS) station keep sensing the medium (listening) for an additional random time called backoff time. A station initiates its transmission only if the medium remains idle for this additional random time

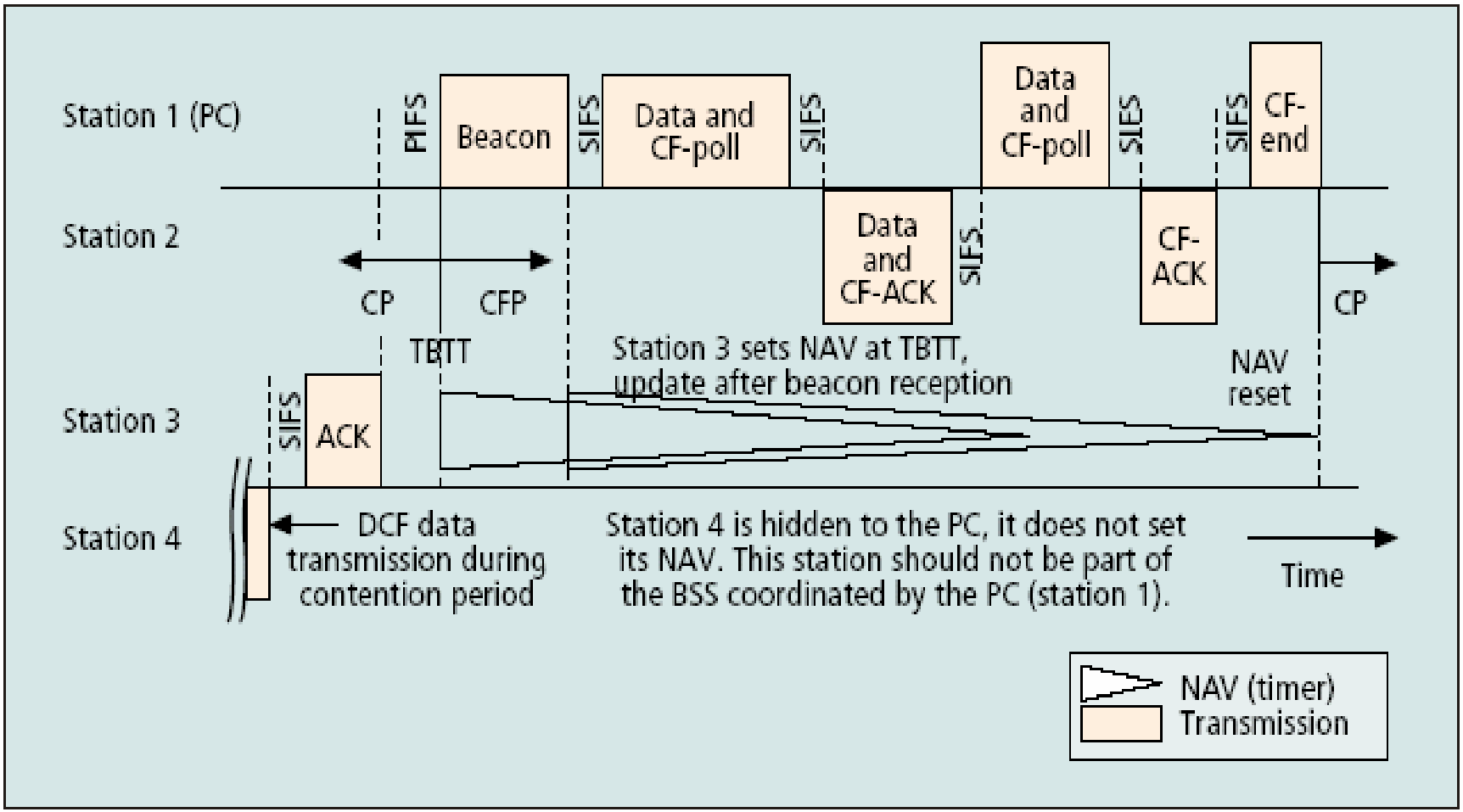
Figure 1: IFS and backoff procedure with random contention window size. Here the transmission station use CW=CWmin (15 slots of 802.11a, and has selected a random backoff time of 12 slots)



A Brief Background on IEEE 802.11 MAC (original) cont.

- PCF (*Point Coordination Function*) to support time bound services
- The PCF provides mechanisms for prioritized access to the wireless medium, and is centrally coordinated by a station called the *point coordinator* (PC) – typically the *access point* (AP)
- PCF has the higher priority than medium access of DCF
- PCF is used for accessing the medium during the CFP (*Contention Free Period*)
- Whereas the DCF is used during the CP (*Contention Free*)

Figure 2: An example of PCF operation. Station 1 is the PC and station 2 is polled. Station 3 detects the beacon frame and updates the NAV to the whole CFP. Station 3 has learnt from earlier beacon that a CFP starts after the TBTT shown here



Limited QoS support applying the DCF and PCF

- In the DCF mechanism of IEEE 802.11 all the stations and data flows have the same priority to access the medium - no differentiation mechanism to support the transmission of data streams with different QoS requirements
- Unsolved problems of PCF: unpredictable beacon delay and unknown transmission duration of the polled stations, etc.
- At TBTT (*Target Beacon Transmission time*) a PC schedules the beacon frames but they only can be transmitted when the medium has been idle for at least a PIFS and because stations can start their transmissions even if the MSDU (*MAC Service Data Unit*) delivery is not finished before the upcoming TBTT
- The fragmented MSDU delivery causes the unknown duration of the polled stations

Part II: QoS Support Mechanisms of IEEE 802.11e

- HCF (*Hybrid Coordination Function*) is introduced and it defines two medium access mechanism:
- *Contention-based channel access* referred to as enhanced distributed channel access (EDCA)
- *Controlled channel access* (including polling) as HCF controlled channel access (HCCA)
- The EDCA is used in the CP only
- The HCCA is used in both CP and CFP phases

(some new concepts)

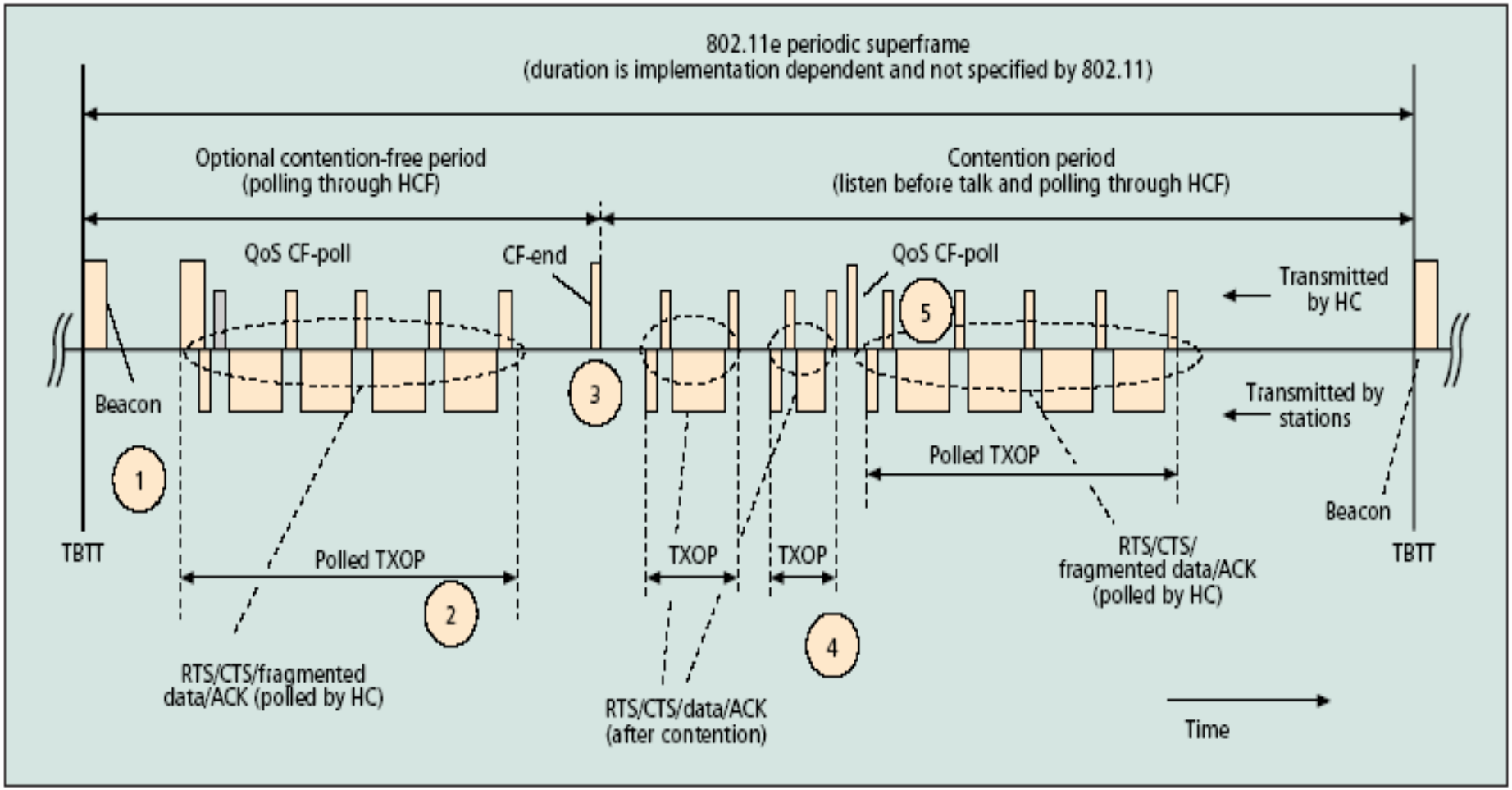
- The central coordinator for all other stations is called the *hybrid coordinator* (HC) similar to the PC residing in the AP
- The multiple parallel backoff processes in a stations of 802.11e are referred as *backoff entity*
- QBSS (QoS BSS): a BSS including an 802.11e-compliant HC

Part III: The QoS Enhancement in IEEE 802.11e

- *Basic improvements of the legacy 802.11 MAC* :

- *Transmission opportunity* (TXOP) is defined by its starting time and duration (TXOP-limit) that are regularly distributed by HC within an information field of the beacon
- TXOPs obtained via contention-based medium access are referred to as EDCA-TXOPs
- A TXOP obtained by the HC via controlled medium access is referred to as HCCA-TXOP
- Or polled TXOP during CP when a backoff entity receives a polling frame (QoS CF-Poll) from HC
- No backoff entity transmits across the TBTT. This reduces the expected beacon delay
- An 802.11e backoff entity is allowed to transmit frames directly to another backoff entity in a QBSS, without involving communication with AP

An example of an 802.11e superframe where the HC grants TXOPs in contention-free period (CFP) and contention period (CP)

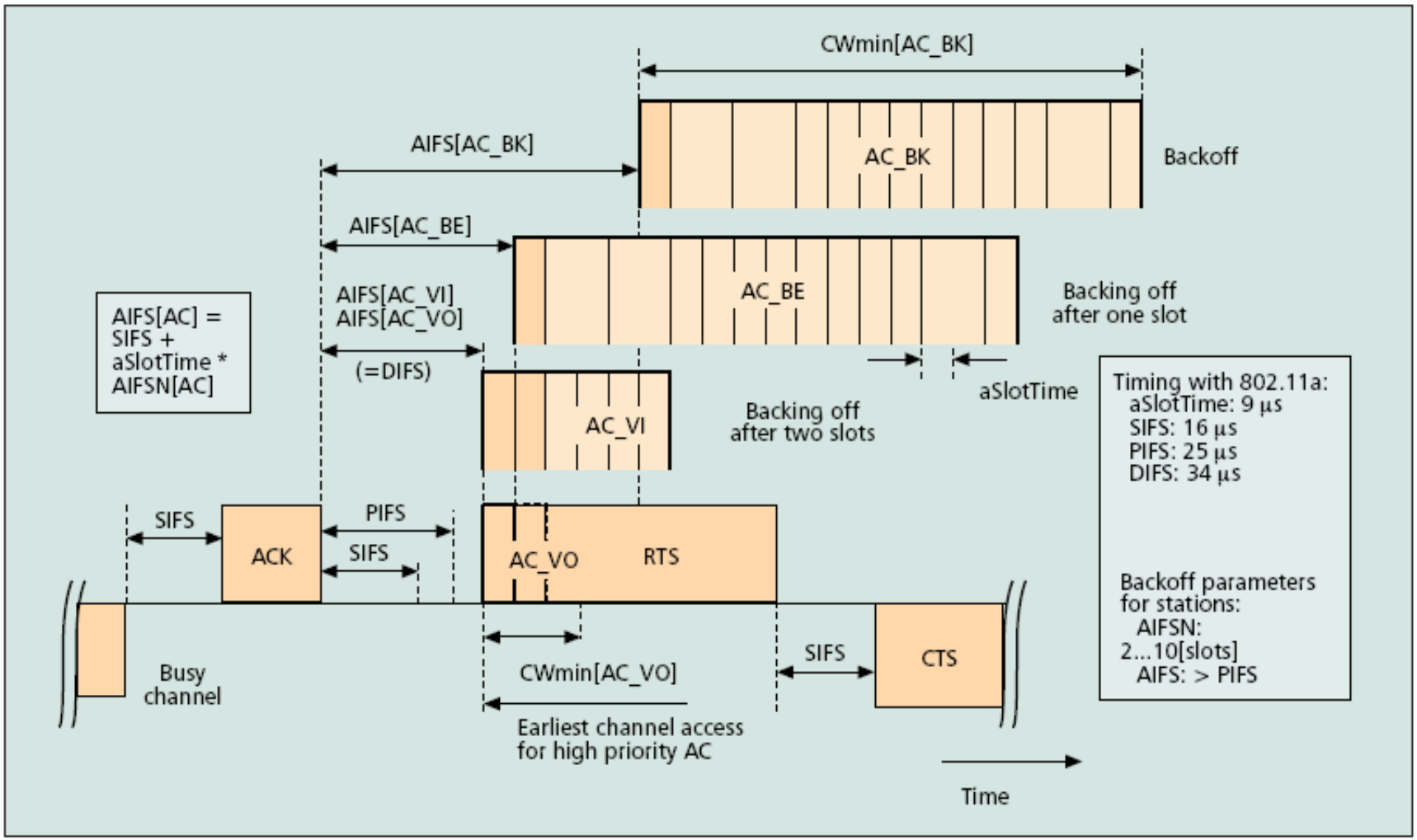


HCF contention-based medium access

- In EDCA, *access categories* (CAs) is introduced. There are up to four CAs existing in every 802.11e station
- The ACs are labeled and prioritized
- AIFSN: *arbitration interframe space number* is introduced instead of IDFS in legacy stations
- *AIFS[AC] = SIFS + AIFSN[AC]*aSlotTime*

	AC_VO	AC_VI	AC_BE	AC_BK
AIFSN:	2	2	3	7
CWmin:	3	7	15	15
CWmax:	7	15	1023	1023

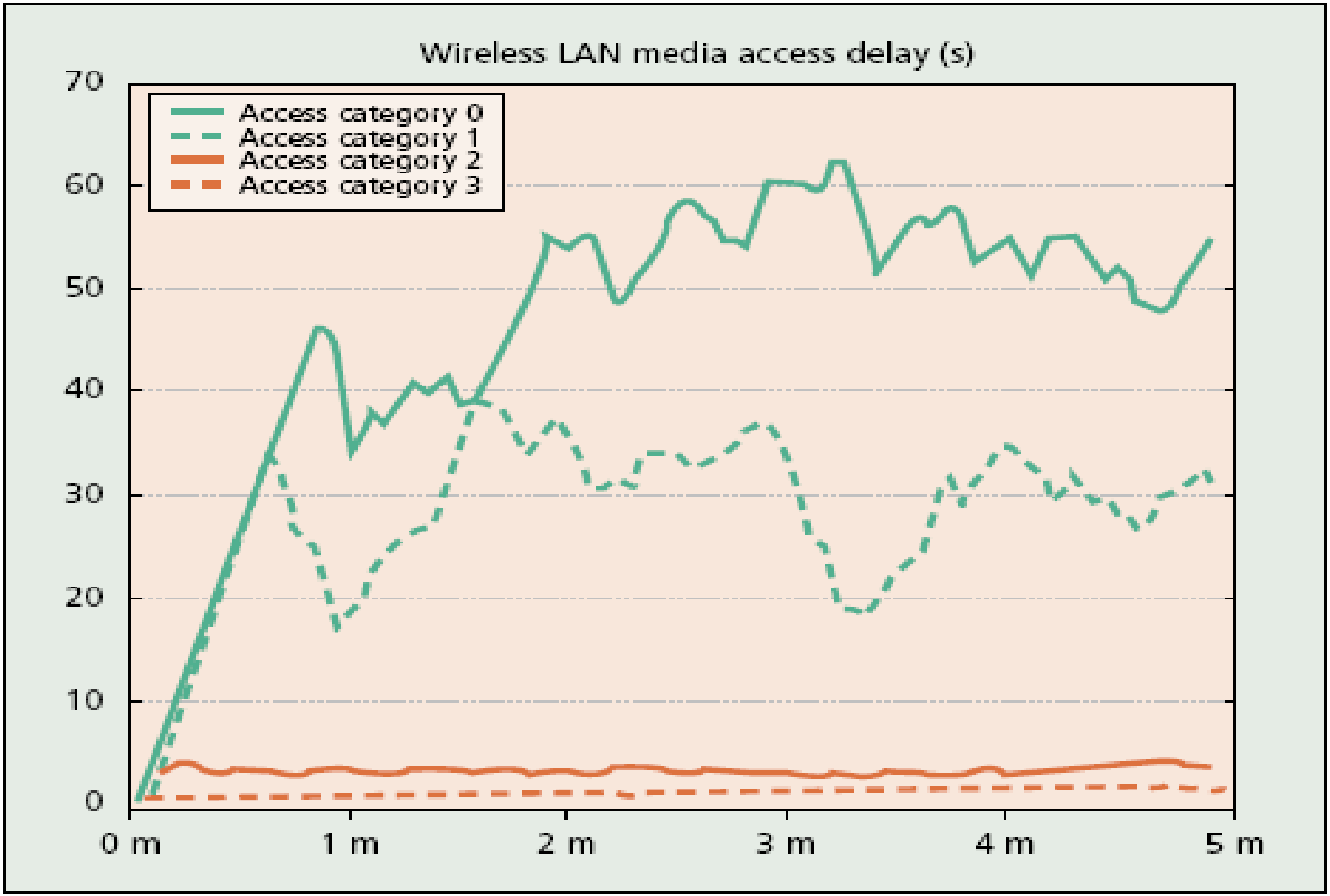
In EDCA, multiple backoff entities contend for medium access with different priorities in parallel. The earlier possible medium access time after a busy medium is DIFS



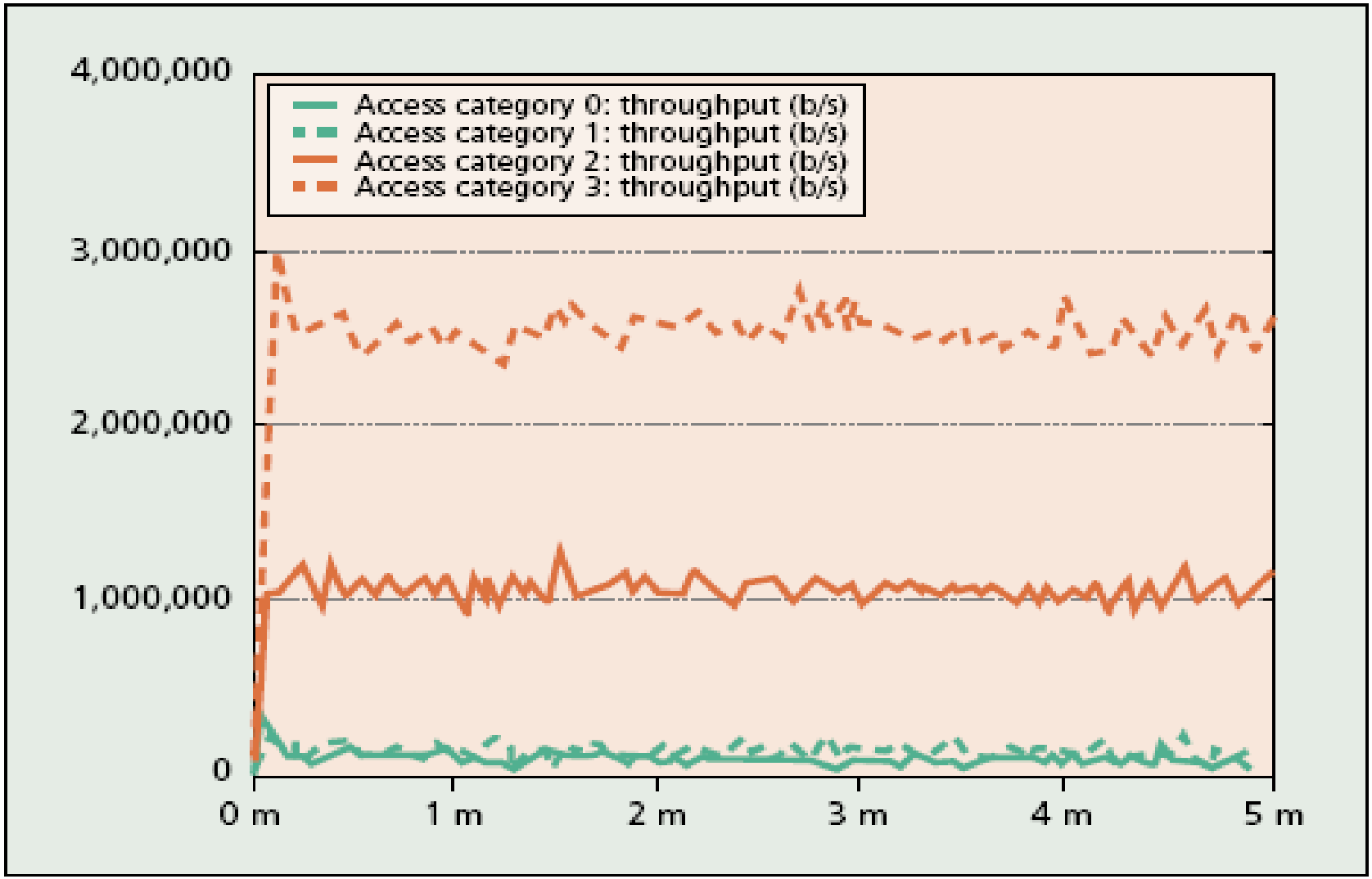
Part IV: The Simulation Evaluation

- In OPNET 802.11b PHY, four stations with EDCA mechanism modification and the other parameters such as TXOPs are omitted
- For simplicity, any AC getting access to the medium transmits one packet and then releases the channel for next AC
- All four traffic classes were fed into MAC layer from higher layer. They have equal portion of the total data traffic per unit time and the packet had the same size of 1024 bytes
- The traffic AC(00), AC(01), AC(02) were generated according to Poisson process while AC(03) at a constant rate to simulate a voice source

Medium access delay for different ACs



Throughput for different ACs



Part V: The Idea Behind IEEE 802.11e and Further Discussion

- More attention needed to the correlation of the metrics such as throughput, delay and jitter
- The trade-off between priority-based mechanism and the fairness
- Ability to provide predictable QoS
- The overhead: determined by the need for an additional field in the MAC protocol, the number of messages exchanged
- The complexity: the computational requirement of the QoS support mechanism
- Furthermore, the power consumption over the dynamism in the wireless channel characteristics
- The dynamic changeable data rate according to the varying SNR associated with the stations

References

- [1] *Stefan Mangold, Sunghyun Choi, et al* '**Analysis of IEEE 802.11e for QoS Support in Wireless LANs**', IEEE Wireless Communications December 2003.

- [2] *Daqing Gu and Jinyun Zhang*, '**QoS Enhancement in IEEE802.11 Wireless Local Area Networks**', IEEE Communications Magazine June 2003

- [3] *Wasan Pattara-atikom and Prashant Krishnamurthy*, '**Distributed Mechanism for Quality of Service in Wireless LANs**', IEEE Wireless Communications June 2003

Homework

1. List three basic improvements of the legacy 802.11 MAC in the (draft version) 802.11e

2. Explain (shortly) the terms of EDCA, AIFSN, CWmin and CWmax. How they are used by different ACs to contend the TXOPs according to their corresponding priorities in 802.11e in EDCA mechanism