802.11 Task Group E Status

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V1.0

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Development History of 802.11

- ## The first version of 802.11 was completed in July 1997
  - The standard specified three 1 and 2Mbps PHYs – Frequency Hopping, Direct Sequence, and Infrared.

- ## Two High Rate PHY updates were completed in September 1999
  - 802.11a   6 to 54Mbps in the 5GHz band
  - 802.11b   5.5 and 11Mbps in the 2.4GHz band

- ## Other updates
  - 802.11c is a supplement to 802.1d to support 802.11 frames.
  - 802.11-1999 is an update to the main standard to change the MIB from OSI to SNMP encoding, and incorporate various other corrections.
  - 802.11d adds extensions to operate in additional regulatory domains. It is currently being balloted.

Scope and Purpose of Project 802.11E

- **The MAC Enhancements Study Group met from September 1999 through March 2000.**
- **The Project Authorization Request (PAR) for the working group 802.11E was approved in March 2000.**
- **The PAR defines the scope and purpose of the activities of the project:**
  - **Enhance the 802.11 Medium Access Control (MAC)**
  - **Improve and manage Quality of Service**
  - **Provide classes of service**
  - **Provide enhanced security and authentication mechanisms**
  - **Consider efficiency enhancements in the areas of the Distributed Coordination Function (DCF) and Point Coordination Function (PCF)**

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802.11E (TGe) Project Milestones

- ## March 2000 – Albuquerque, NM
  - PAR Approved, Task Group 802.11E formed
  - First set of proposals and papers on MAC Enhancements.

- ## May 2000 – Seattle, WA
  - Refinement of Requirements and Evaluation Criteria
  - Continuation of presentation of papers and proposals

- ## July 2000 – La Jolla, CA
  - Adoption of Requirements and Evaluation Criteria

- ## September 2000 – Phoenix, AZ
  - TGe subdivides into QoS, Security, and DFS/TPC sub groups. DFS/TPC is made into a new study group (SMa – Spectrum Managed 802.11a).
  - TGe QoS and Security subgroups hold interim teleconferences and meetings during October.
  - Consensus reached in QoS group – foundation of "baseline proposal" established

- ## November 2000 – Tampa, FL
  - First presentation of QoS Baseline proposal
  - Convergence of security proposals

- ## January 2001 – Monterey, CA
  - Target for first draft
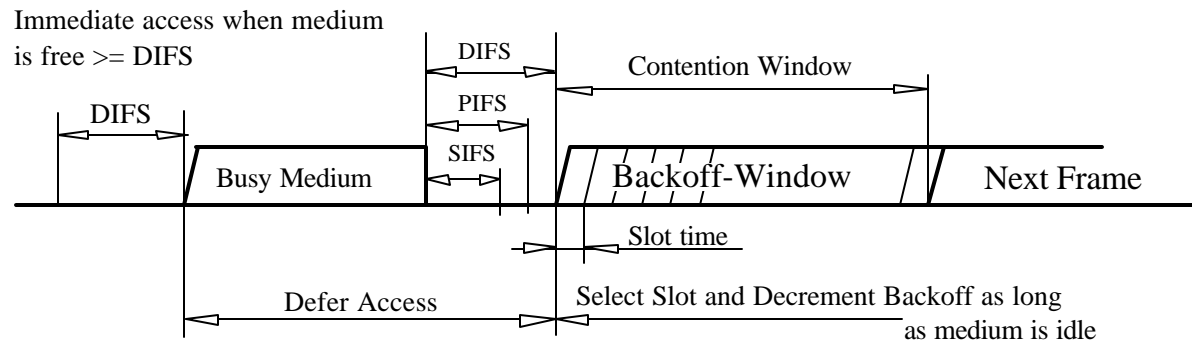
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Review of the existing 802.11 MAC

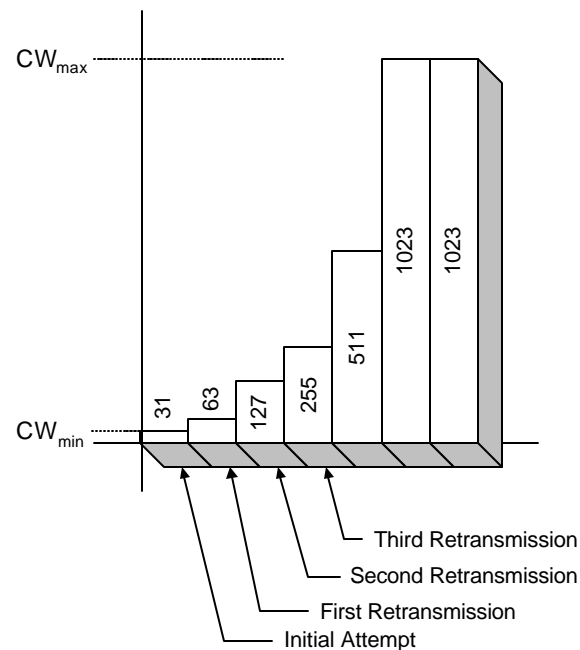# 802.11-1999 review – DCF Operation

- **Random Backoff**
    - **The protocol is designed to reduce the collision probability at the point where collisions would most likely occur — just after the medium becomes idle following a busy medium. This is because multiple STAs could have been waiting for the medium to become available again. The random backoff procedure resolves this conflict.**
    - **If a station desires to transmit, but senses a busy medium, it will delay (backoff) for an additional random amount of time after the DIFS.**
    - **The station selecting the shortest backoff will transmit first. Other stations will hear that transmission and defer.**

Immediate access when medium
is free >= DIFS

DIFS

DIFS

PIFS

SIFS

Contention Window

Busy Medium

Backoff-Window

Next Frame

Slot time

Defer Access

Select Slot and Decrement Backoff as long
as medium is idle

802.11-1999 review – DCF Operation

- **Random Backoff, contd.**
  - When a station selects the backoff time, the value is chosen within the Contention Window (CW). The backoff time is computed as a random number in the range between 0 and the current CW value.
  - The CW ranges from 31 slots (620uS) to 1023 slots (20.46mS) for DS PHYs. The CW value is incremented after failed transmissions, and decremented after successful transmissions.
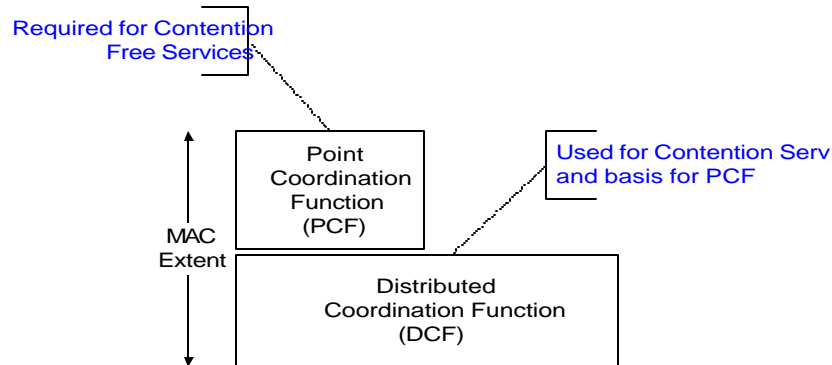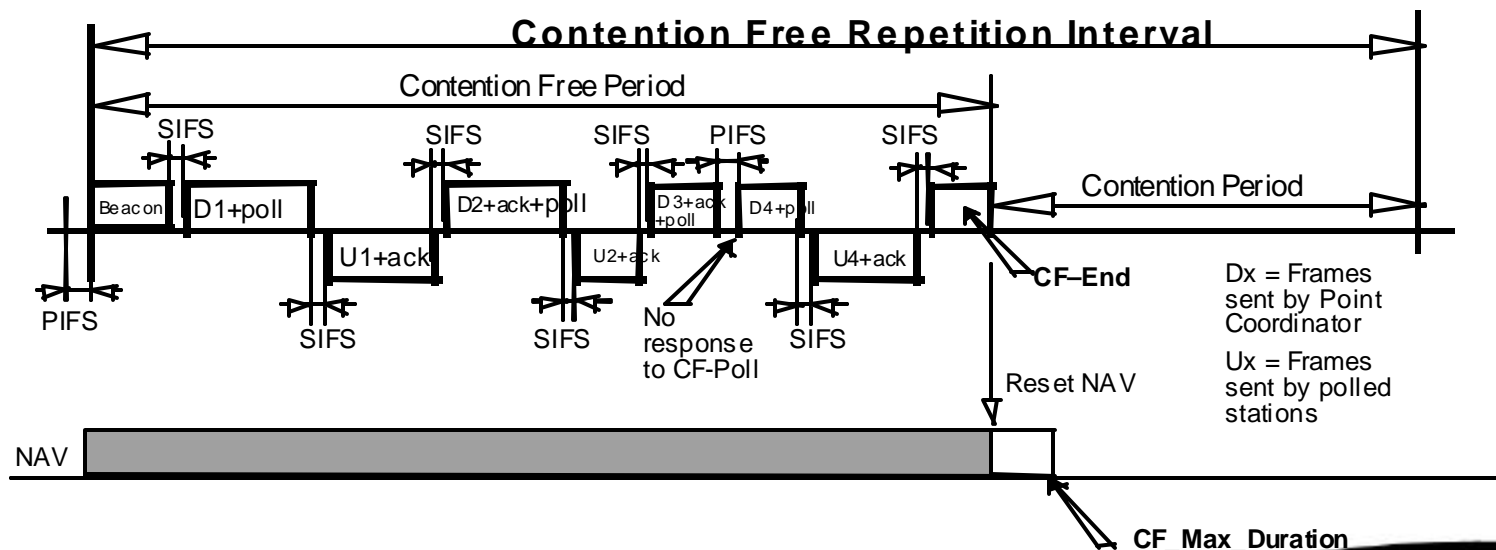
802.11-1999 review – PCF Operation

Required for Contention
Free Services

```
                    ┌─────────────────┐
                    │      Point      │        Used for Contention Serv
                    │  Coordination   │        and basis for PCF
                    │    Function     │
                    │     (PCF)       │
          MAC       └─────────────────┘
         Extent        ┌──────────────────────┐
                       │     Distributed      │
                       │ Coordination Function │
                       │        (DCF)         │
                       └──────────────────────┘
```

Figure 1, MAC Architecture

- **PCF is an optional mode of operation, built on the DCF.**
  - **Time is divided in to a Contention Free Period, where access is controlled by the Point Coordinator, and the Contention Period, where the basic DCF rules apply.**
  - **Stations that do not support PCF may still participate in a PCF BSS using only DCF operation.**

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802.11-1999 review – PCF Operation

- **Polling**
  - The PC maintains a Polling List of all associated CF-Pollable STAs.
  - The PC polls all STAs during the CFP, even if there is no traffic to be sent from the PC to the STA. The STA always responds.
  - For efficiency, the PC uses Data+CF-Poll frames and Data+Ack+CF-Poll frames.

Contention Free Repetition Interval

Contention Free Period

SIFS SIFS SIFS PIFS SIFS

Contention Period

Beacon | D1+poll   D2+ack+poll   D3+ack+poll | D4+poll

U1+ack   U2+ack   U4+ack

CF–End

PIFS

SIFS   SIFS   No response to CF-Poll   SIFS

Reset NAV

Dx = Frames sent by Point Coordinator

Ux = Frames sent by polled stations

NAV

CF_Max_Duration

QoS Background and Architecture

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Background – QoS proposals

- The IETF concepts of "Integrated Services" and "Differentiated Services" have corresponding groups of proponents within 802.11 Task Group E.

- The needs of "Integrated Services" are to provide end to end connection oriented QoS with support for streaming and centralized scheduling.

- The needs of "Differentiated Services" are to provide a simple mechanism for allowing traffic priorities as part of the medium access mechanism.

- These needs are different enough that the QoS group was unable to find a single mechanism that could meet both sets of requirements.

- The QoS baseline proposal contains two different access methods and 3 QoS Levels to accommodate both of the QoS philosophies.

QoS Medium Access Mechanisms

| 802.11 | DCF $\Rightarrow$ PCF |
| 802.11E | EDCF $\Rightarrow$ EPCF |
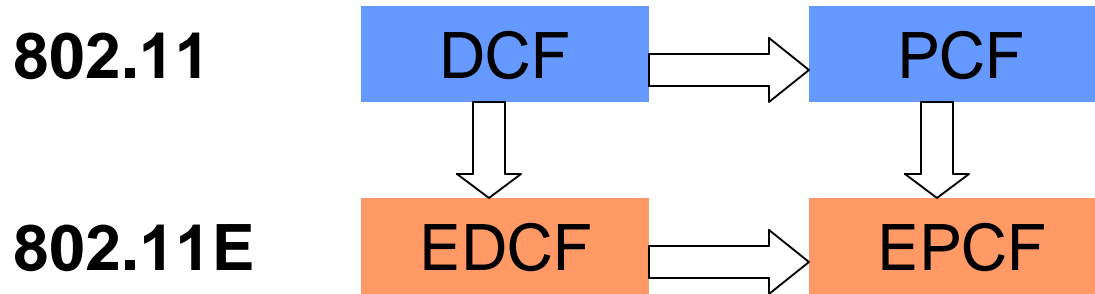
- **In the existing 802.11 standard, the PCF (Point Coordination Function) is optional, and build upon the DCF (Distributed Coordination Function).**

- **In 802.11E, the two existing mechanisms are enhanced for QoS in an upward-compatible manner to produce the EDCF and the EPCF.**

QoS Levels

	Channel Access	Scheduling Policy
Level 3	EPCF with EDCF	Parameters
Level 2	EPCF with EDCF	Priorities
Level 1	EDCF	Priorities
Level 0	Legacy DCF	None

- **The QoS Levels are the result of the capabilities of the two enhanced access mechanisms, and two scheduling policies.**
- **802.11E compliant devices implement Level 1, 2, or 3.**
- **Each QoS level is a strict superset of those below it.**
- **All combinations of levels will interoperate, and provide QoS with the capabilities of the lowest level supported.**
- **Level 1 provides superior QoS performance than Level 0 (Legacy 802.11)**

QoS Scheduling Policies

- **Level 1 and 2 implement 8 priorities.**
  - The 8 priorities are those defined by the 3 bit priority field in the existing MAC SAP (Service Access Point).
  - The 8 priorities are global for the station.
- **Level 3 allows 8 priorities *per connection* with Parameterized QoS**
  - Connections are identified by the source/destination pairs of MAC addresses, and the priority.
  - Each connection is mapped to a traffic specification which instructs the MAC how to best schedule those MSDUs.
  - Level 3 operates only when using the PCF, where medium access in the CFP (Contention Free Period) is scheduled by the point coordinator.
  - The support of priorities per connection allows the scheduling of specific streams at specific times (Transmit Opportunities) in the CFP to minimize latency and jitter.

The Enhanced DCF

**Based on IEEE 802.11
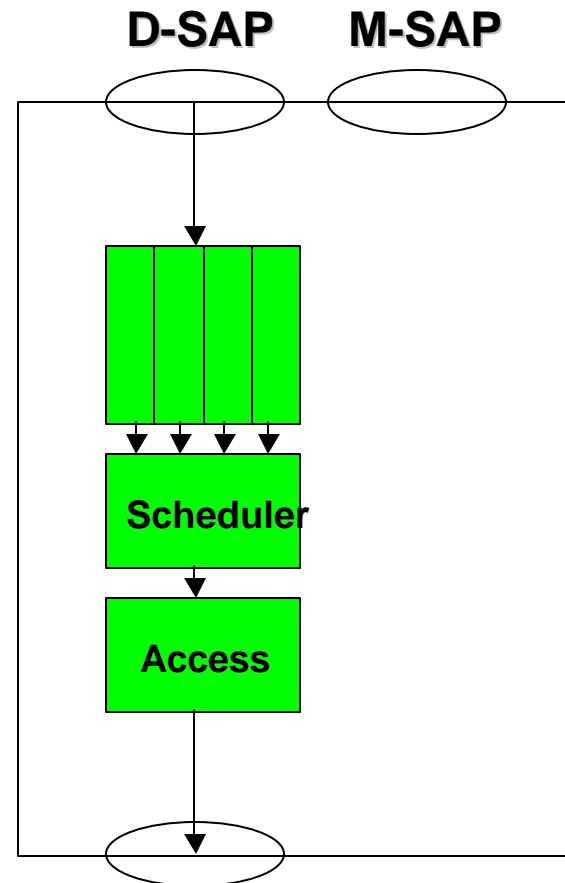document 00/361**

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The Enhanced DCF concept

**Standard 802 Data SAP
With 3-bit traffic class**

**Number of Queues
depends on QoS level**

MPDU Scheduler

**The channel access
function is independent
of the scheduler**


D-SAP   M-SAP

Scheduler

Access

The Enhanced DCF operation

- **The enhanced DCF scheduling mechanism may be used in levels 1 and 2.**
  - In Level 2 PCF: During the CFP the random number generation aspect of vDCF can be the schedule mechanism.
    - While the PCF determines the Transmit Opportunity (Tx-Op)
  - During the CP (or all the time in Level 1) the vDCF scheduling and access mechanism is active.
    - Where the parallel DCF backoff mechanism is generating the Tx-Ops.

- **In an ESS a "Load monitor" function in the AP will determine the CW per priority class, which is to be adopted by every station.**
  - The translation from "Load to CWx vectors" is NOT standardized.

- **In an IBSS a default CWx map is assumed, but a CWx distribution by a "Load Monitor" function will override the default.**
  - In IBSS a 'Load Monitor" function is not mandatory.
  - The default assumes CW=31 as the "Best Effort" reference.

The Enhanced DCF – V-DCF Mechanism
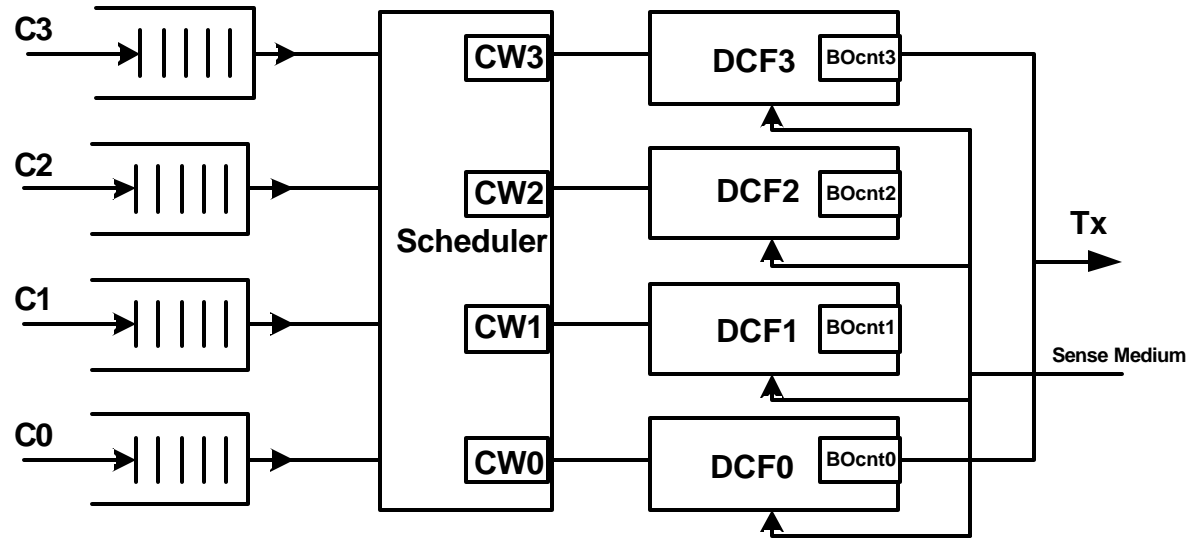
- **Access differentiation is controlled by a Contention Window parameter per priority category (CWx).**
  - Multiple DCF's run in parallel, each with an individual Backoff counter.
  - The scheduling function is based on a random number generated per access priority level. Individual CWx parameters cause a differentiation in access ratio according to the proportion: 1/CW3 : 1/CW2 : 1/CW1 : 1/CW0
  - This insures that even if the high priority queues are full, the lower priority queues will get some access, but a proportionally smaller amount.
- **At a local collision, the highest priority frame is transmitted, while the other DCF defers and generates a new Backoff.**

The Enhanced PCF

Based on IEEE 802.11 document 00/071r1

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The Enhanced PCF

- **The Enhanced PCF provides new services and frame formats to support higher-layer, end-to-end QoS mechanisms:**
  - A QoS Data Service supporting Virtual Streams (VS) with specified QoS parameter values and including priority, data rate, delay and jitter bounds.
    - Mapped to source and destination address pairs, with 8 priorities per stream.
  - The enhanced PCF scheduler allocates bandwidth to virtual streams and asynchronous traffic:
    - New forms of CF-poll allow precise dynamic control with reduced overhead.
    - Persistent transmission scheduling provides QoS-friendly power save operation.
  - An adaptive technique prevents interference among overlapping, point-coordinated BSSs operating on the same channel, while allowing non-interfering transfers to occur in parallel, even when the overlapping BSSs are not part of the same ESS.
  - Direct station-to-station transfers are permitted in a QoS-capable BSS (QBSS).
  - A dynamic wireless repeater function can extend the spatial coverage of a QBSS.

Enhanced PCF Operation

- **The enhanced point coordination function understands QoS-related parameters:**
    - **Each enhanced station (ESTA) has a classification entity (CLSE) above the MAC to identify the virtual streams for incoming MSDUs.**
        - **The CLSE supports Layer 3 QoS standards such as RSVP and SBM. These functions are above the MAC and outside the scope of 802.11. They communicate to the 802.11E enhanced MAC through the 802 Data SAP and Management SAP.**
    - **Each QoS-supporting Level 3 BSS (QBSS) is controlled by an enhanced access point (EAP) with an enhanced point coordinator (EPC).**
        - **The EPC includes a time allocation management entity (Scheduling Function) that allocates transmission opportunities (TXOPs) to ESTAs.**
        - **TXOPs have defined starting times and maximum durations. ESTAs make local decisions about which MPDUs to transmit during each TXOP.**
        - **A QBSS may have ESTA(s) that operate as bridge-portals (BPs) to allow alternate or multiple points of connection to the infrastructure.**
        - **Spatial coverage of a QBSS may be extended by dynamically-activated Repeater Point Coordinators (RPCs).**

Enhanced PCF Compatibility

- The proposed Level 3 QoS functions are a direct extension of existing 802.11 functions:
    - Reserved bits in existing frame formats are defined for the new functions:
        - Capability Information bit 8 indicates QoS (and EPC in conjunction with CF bits).
        - Data subtype bit 7 is set to 1 to indicate "stream data" in QoS MPDUs.
        - Duration/ID bits 0-13 contain QoS control information during the CFP (msb=10).
        - Several QoS-related Control and Management frame subtypes are defined.
    - Existing stations can communicate in a QBSS during the CP (under DCF).
    - Existing CF-pollable stations may be polled by an EPC during the CFP.
    - The BSS overlap mitigation procedure is effective (but non-optimal) for reducing interference between QBSSs and a non-QoS BSSs.
    - All stations must be CF-conformant as specified in IEEE 802.11-1999.
- The proposed QoS support is intended to operate with existing authentication and privacy mechanisms, as well as any enhanced security facilities adopted as part of 802.11E.

Centralized vs Distributed Contention

- **Fully distributed (without a PC):**
  - AP needs to contend, especially severe for asymmetric traffic loads.
  - A large data burst will result in a large number of MPDUs, *each* of which has to contend for transmission (resulting in lots of contentions if there are other data STAs sending data) and is likely to transmit beyond the TBTT (bad for other time-bounded frames).
  - Backoff for collision resolution is based on the contention outcome of the backoff STA itself, and is far from being optimal.
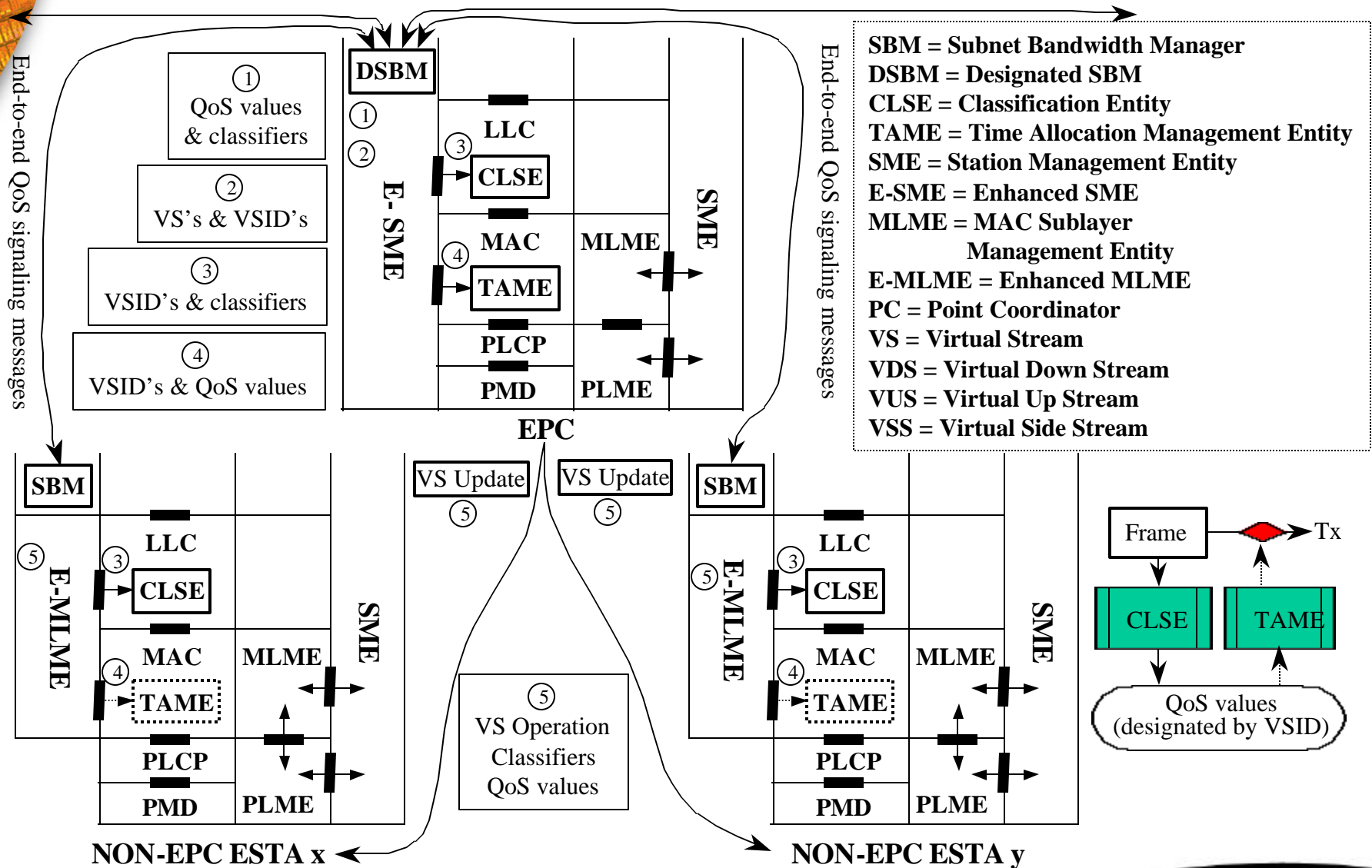
Centralized vs Distributed Contention

- **Partially distributed (with a PC):**
  - Contention and backoff under the DCF has the same shortcomings as noted above.

- **Centrally controlled:**
  - Any data burst needs to contend at most once to send a small RR frame, and its transmission is completely under the control of the PC, with the contention never going beyond the TBTT.
  - Collision resolution is based on the contention outcome of all STAs and can be optimised.
  - Significantly improved data access delay and channel throughput performance.

Medium Access in the Enhanced PCF

- ## Transmit Opportunities Tx-Ops
  - The EPC informs Stations of Tx-Ops using the Schedule frame.
  - Tx-Ops can be one-time or persistent.

- ## Centralized Contention
  - Centralized Contention is the mechanism stations request Tx-Ops from the Point Coordinator.
  - The Reservation Request (RR) frames are sent by Stations during the Contention Free Period (CFP).
    - With today's PCF, reservation requests would have to contend for access using DCF rules during the Contention Period.
  - Stations transmit RR frames in a contention interval using a probabilistic mechanism.

- ## Aggregation
  - Reduces PHY overhead by transmitting multiple MSDUs addressed to the same destination in a special frame called a Container.

- ## Selective Acknowledgement
  - An ACK policy field is added to the Duration/ID encoding to allow traffic classes with delayed acknowledgement and no acknowledgement.

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VS Service Interfaces Reference Model

SBM = Subnet Bandwidth Manager
DSBM = Designated SBM
CLSE = Classification Entity
TAME = Time Allocation Management Entity
SME = Station Management Entity
E-SME = Enhanced SME
MLME = MAC Sublayer
           Management Entity
E-MLME = Enhanced MLME
PC = Point Coordinator
VS = Virtual Stream
VDS = Virtual Down Stream
VUS = Virtual Up Stream
VSS = Virtual Side Stream

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802.11E Security Overview

**Based on IEEE 802.11
document 00/321**

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802.11E Security Overview

- **Adequacy of RC4 is in question.**
  - **Call for papers**
  - **AES has been recommended**
- **40 bit RC4 is insufficient**
- **Mutual authentication is mandatory.**
- **Key distribution**
  - **The current standard does not provide for key distribution.**
- **Per session keys are needed**

802.11E Security Overview

- **802.11E security related clauses should reference other documents in an annex and then mandate their implementation.**

- **802.1X**

    - **802.11E needs to enhance the 802.11 SAP to allow the 802.11 MAC to pass association ID's to 802.1X for use with virtual port ID's.**

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802.11E Security Overview

- **There are four elements to the security system**
    - **Authentication client**
    - **Authentication relay**
    - **Authentication server**
    - **Authorization control**
- **There are up to three protocols**

802.11E Security Overview

- **There needs to be two negotiation protocols, one at the MAC layer and one at a higher level.**
- **MAC level negotiation includes**
  - **Authentication algorithm**
    - **Current 802.11**
    - **Use upper layer**
  - **Privacy algorithm**
    - **40 bit RC4**
    - **104 bit RC4 (frequency called 128 bit)**
    - **other**
  - **Key establishment algorithm**
    - **Current 802.11**
    - **Use upper layer**
  - **Key expiration**
    - **Current 802.11**
    - **Use upper layer**

802.11E Security Overview

- **Higher level includes**
  - **authentication algorithm**
  - **key establishment algorithm**
  - **key expiration**
  - **sub key derivation algorithm**
    - **one way hash**
    - **other**
  - **data integrity algorithm**
- **What is authenticated are credentials. What these credentials represent are independent of the IEEE 802.11 standard.**

Conclusion

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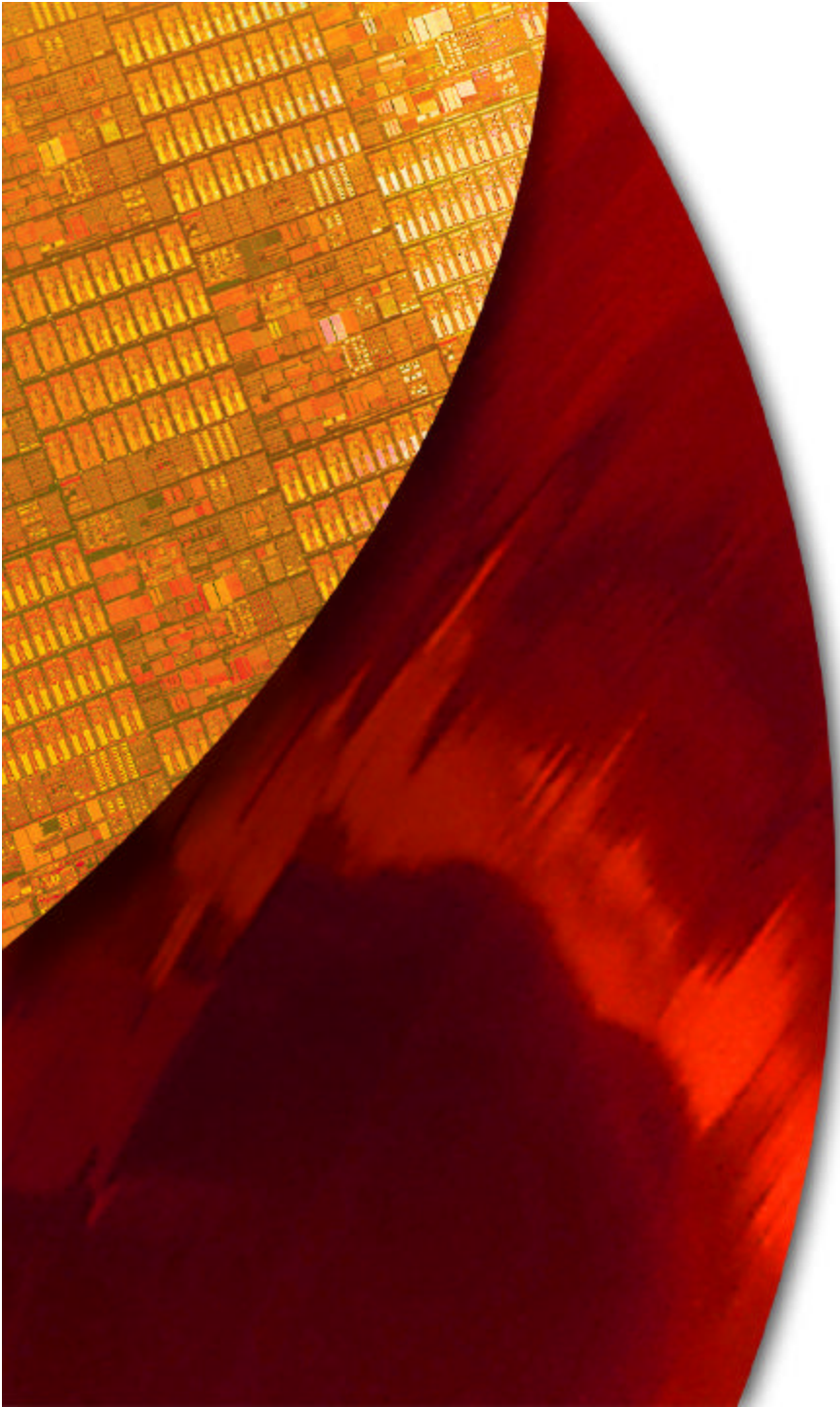
Next Steps

- **The QoS Ad Hoc group will present the Baseline Proposal to the full Task Group E at the November Plenary in Tampa.**
  - Acceptance of the baseline is likely, since all of the members with proposals and input have participated in the creation of the baseline, and approve of it.
- **The Security Ad Hoc group will continue to review proposals and form a baseline or an initial draft.**
- **Once the QoS and Security Ad Hoc groups have have reached agreement, the editor will begin writing the draft text for the standard.**
- **When the draft has been completed and approved by Task Group E it begins the balloting process.**