# IEEE 802.11 Task Group E
## MAC Enhancement Proposal
## -- Tiered Contention Multiple Access (TCMA)

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# Outline

- Introduction
- Tiered Contention Multiple Access
- Simulation Result
- Conclusion

# Introduction

- Summarizing Proposal Authors
  - Virtualized DCF (VDCF)
    - AT&T, Agere System, Atheros, Intersil, Lucent
  - Probability DCF (PDCF)
    - TI
  - TCMA
    - AT&T
  - Enhanced Channel Access
    - AT&T, Agere System, Atheros, Intersil, Lucent, TI

# Introduction

- History
  - DCF
    - Single Contention Windows
  - VDCF
    - Multiple Contention Windows
    - Contention Offset (Multiple IFSs)
    - Internal Contention

# Introduction

- ## History(con't)
  - ### pDCF
    - Dynamic Tuning Backoff time according to Traffic Category Permission Probabilities (TCPP)
    - No Internal Contention
  - ### TCMA
    - UAT (Non-decrementing offset)
    - UC Update/Packets Aging
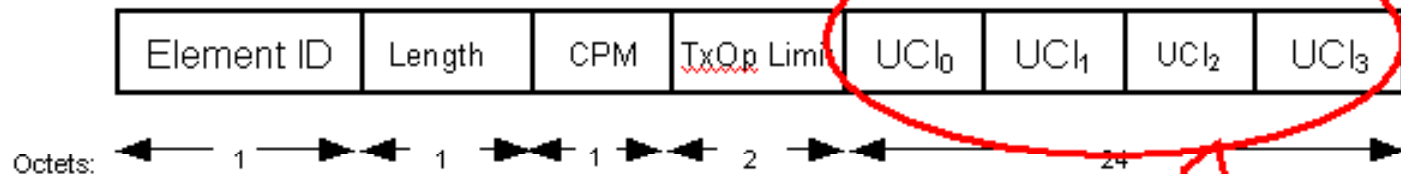    - Decreasing retransmission CW
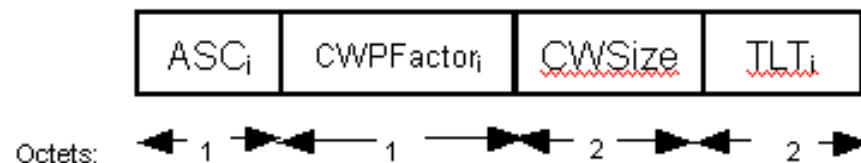
# TCMA

# TCMA (Element Frame Format)

... ...

| 10 | EDCF Parameter Set | The EDCF Parameter Set element is only present within Probe Response frames generated by ESTAs in a BSS that supports EDCF. |
|----|-------------------|---|

Information Element: (EDCF Parameter Set)

(CMP → Contention Priority Mapping)

| Element ID | Length | CPM | TxOp Limit | UCI$_0$ | UCI$_1$ | UCI$_2$ | UCI$_3$ |
|------------|--------|-----|------------|---------|---------|---------|---------|

Octets:      1          1        1        2                        24

Urgency Class Information (UCI) Tuple Format

| ASC$_i$ | CWPFactor$_i$ | CWSize | TLT$_i$ |
|---------|---------------|--------|---------|

Octets:    1          1            2        2

# TCMA (New Terms)

- Universal Station (USTA):
    - Universal station refers to either an STA or an ESTA

- Urgency Class (UC):
    - Urgency classes are a mechanism by which the MAC differentiates frames of different priorities and traffic categories. Each priority value is mapped to an urgency class.

- Urgency Arbitration Time (UAT) / Arbitration Slot Count (ASC):
    - UAT = SIFS + ASC*SlotTime

# TCMA (New Terms) (con't)

- ## TLT: Transmit LifeTime
    - Indicating the maximum number of time units (TUs) allowed to transmit an MSDU of urgency class i.
    - Packets will be discarded according to this timer, not number of retransmission.

# TCMA

- Priority to Urgency Class Mapping

| Priority Value | Urgency Class |
|:---:|:---:|
| 1 | 0 |
| 2 | 0 |
| 0 (Default) | 1 |
| 3 | 1 |
| 4 | 2 |
| 5 | 2 |
| 6 | 3 |
| 7 | 3 |

# TCMA (Feature)

- UAT
- Aging
- Scheduling (Internal Contention)
- CW

# TCMA (UAT)



BCUT

BCPT

Node C

Node B

Node A

transmission

$t_0$

End of last
transmission
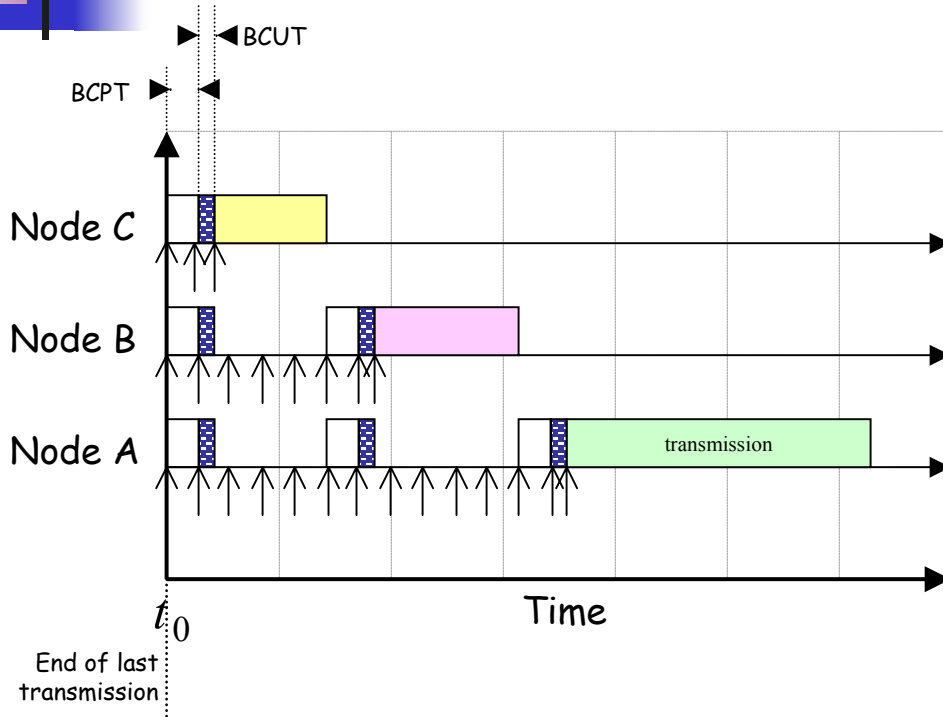
Time

**For legacy stations:**

BCPT=DIFS

BCUT=slot time

Example

All nodes are legacy stations with
backoff counters m at $t_0$ equal to:

m(A)=3; m(B)=2; m(C)=1

BCPT = backoff counter preparation time
BCUT = backoff counter update time

# TCMA (UAT) (con't)

BCPT = backoff counter preparation time
BCUT = backoff counter update time

BCUT

BCPT

Node C

Node B

Node A

transmission

Time

$t_0$

End of last
transmission
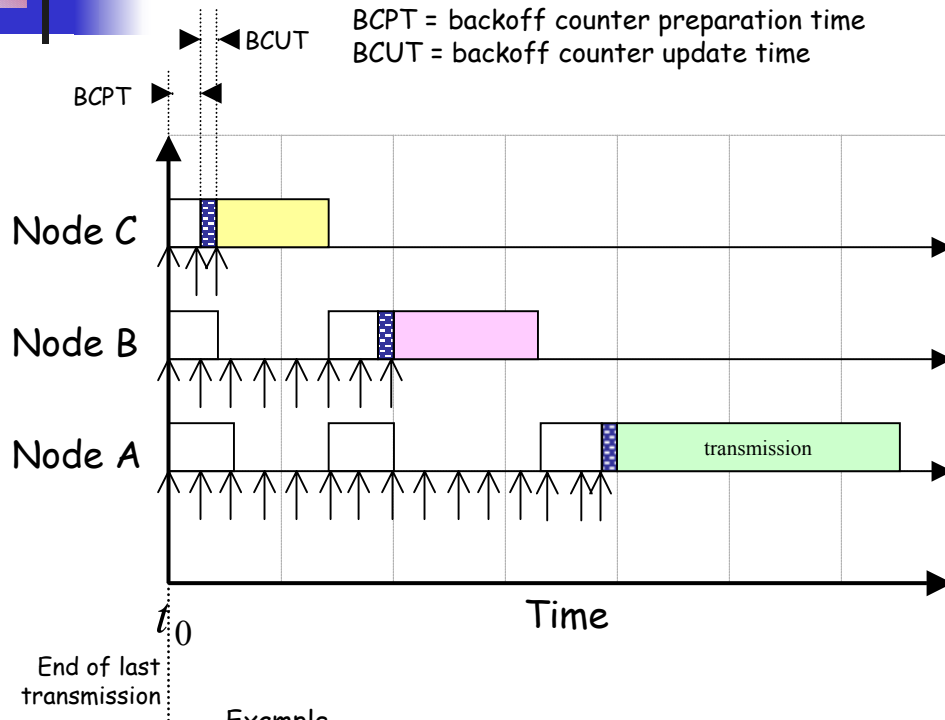
Example
**The backoff counter m at** $t_0$ **is equal to 1 for all nodes;** m(A)= m(B)=m(C)=1

Transmit urgency ranking: (C, B, A); hence,
UAT(A) >UAT(B)>UAT(C)

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TCMA Protocol Backbone

- Each urgency class is assigned a different urgency arbitration time (UAT) whose length decreases with increasing urgency.
- *Arbitration Time* = interval that the channel must be sensed idle by a node before decreasing its backoff counter.
- In congestion:
  - Higher urgency packets dominate the channel, as lower urgency packets get less of a chance to transmit
  - Lower urgency packets do not collide with higher urgency packets.

For stations with classification i= 0,1,...

$$UAT_i = h + i \cdot d$$

# TCMA (Aging)

- Averting Packet Aging
  - **There are nPC=8 priority classes defined for all traffic packets which are permanently assigned to a packet once generated.**
  - **There are nUC=N urgency classes employed for channel contention**

# TCMA (Aging) (con't)

- Averting Packet Aging
  - **The urgency class of a packet is updated in real time so that it**
    - reflects both the priority class of the packet and the speed with which packets of different traffic classes and ages (the time since arrival at the queue) must be transmitted
    - relies on the performance observed in real time

# TCMA (Aging) (con't)

- Averting Packet Aging
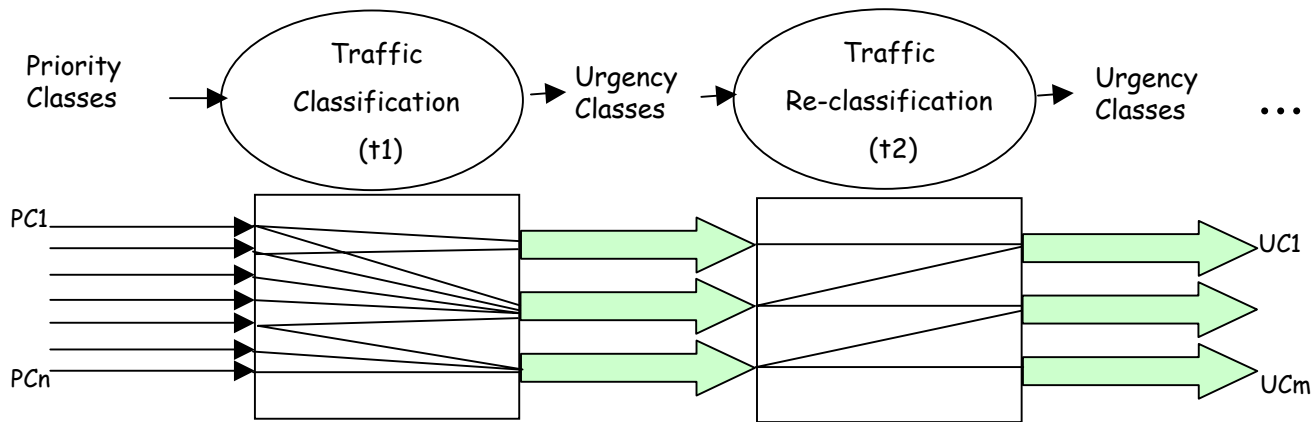
# TCMA (Scheduling)

- Scheduling of Competing Traffic Stream at a Node
  - Parallel queues shall be maintained for each class at a node, each adhering to backoff principles consistent with that class
    - Packets will change queues when their urgency classifications are adjusted
    - A packet will leave its queue if its transmission is cancelled due to excessive latency; the age threshold, aAgeLimit, will be class dependent

# TCMA (Scheduling) (con't)

- Scheduling of Competing Traffic Stream at a Node
  - When a packet's backoff counter becomes 1 it shall be placed in the node's access buffer; in case of a tie, the higher urgency packet is selected
  - Packets generated by stations with multiple traffic types will thus not be disadvantaged

# TCMA (Scheduling) (con't)

- Scheduling of Competing Traffic Stream at a Node
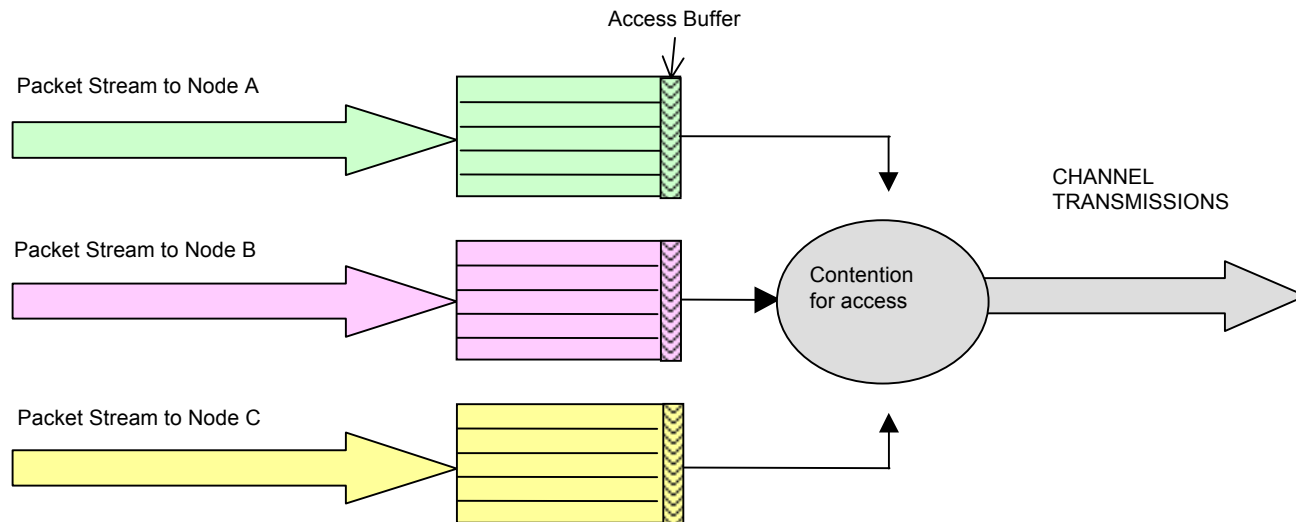
# TCMA (CW)

- Contention Windows Selection Procedure
  - new $CW_i =$

  $\lceil((\text{current } CW_i + 1) \times (aCWPFactor_i/16)\rceil - 1$

  where i is the urgency class of MPDU being retried

  - After every successful attempt to transmit an MSDU or MMPDU of urgency class i, the associated $CW_i$ shall again take the value $(aCWSize_i - 1)$
  - Each time an MSDU or MMPDU of urgency class i is discarded, the associated $CW_i$ shall also take the value $(aCWSize_i - 1)$

# TCMA (Comparison)

- ## Basic Contention Resolution
  - A backoff counter is drawn from a random distribution     (P-DCF,  V-DCF)

- ## Adaptation to Traffic Intensity: Control Mechanism
  - Distributed:  A node (STA or AP) updates traffic from local information as needed

# TCMA (Comparison) (con't)

- Class Differentiation
  - By Initial Backoff Parameters: The parameter ( window size) of the starting backoff distribution vary by class (P-DCF, VDCF)
  - By Arbitration Time:  The waiting time to start countdown after a transmission (DIFS for legacy) varies by class (No conflict)
  - By Retrial Backoff Parameters: The rules to update the backoff distribution following collision vary by class(No conflict)
  - By Dwell-Time Limit:  The maximum time a packet may spend attempting transmission varies by class(No conflict)

# TCMA (Comparison) (con't)

- Averting Packet Aging
  - Urgency Class Upgrade: Packets in certain classes are upgraded dynamically [as their age increases] to reflect their transmission urgency (No conflict)
  - Packet Expiration: Packets are eliminated from queue when queueing times reach class-specific thresholds (No conflict)
- Scheduling of Competing Traffic Streams at a Node
  - Parallel Queues:  Class specific queues are maintained at a node with own backoff countdown(No conflict)

# Simulation Result

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# Simulation Result

- TCMA and V-DCF are compared for two network configurations and various traffic loads
- Three priority classes are considered: High, Medium, and Low
    - Packets from legacy stations are treated the same as medium priority packets
- The following statistics are plotted for stream aggregates referred to as "calls":
    - Total throughput for all calls (bits per sec)
    - Goodput by call (bits per sec)
    - Goodput/Application load by call
    - Data sent by call (bits per sec)
    - Dropped traffic by call (bits per sec)
    - Media access delay (queueing plus contention time) by call (sec)
    - Retransmissions by call (packets per sec)

# Simulation Result

- ## Class Description

| Class Name | UAT | Initial Backoff Range | Persistence Coefficient* |
|---|---|---|---|
| TCMA Top | SIFS +TimeSlot | [1, 15] | 1.5 |
| -- Medium [Legacy] | SIFS+2*TimeSlot | [0,31] | 2 |
| -- Low | SIFS+3*TimeSlot | [0,31] | 2 |
| | | | |
| VDCF Top | SIFS+2*TimeSlot | [0, 15] | 2 |
| -- Medium [Legacy] | SIFS+2*TimeSlot | [0, 31] | 2 |
| -- Low | SIFS+2*TimeSlot | [10, 41] | 2 |

# Simulation Result
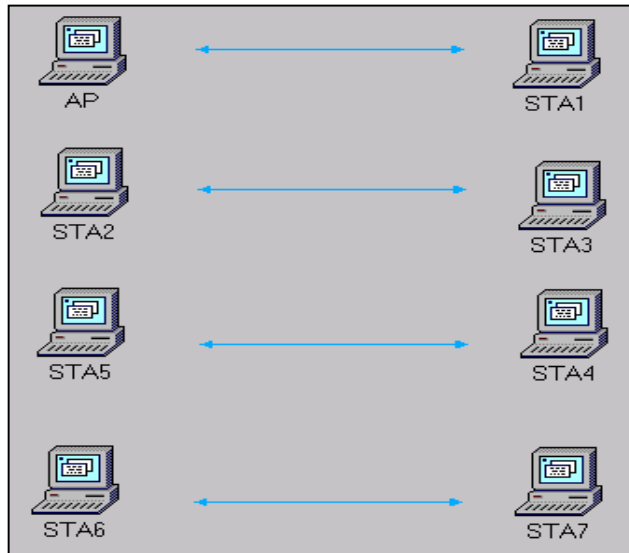


*Traffic*
8 stations generate  4 bi-directional streams;
stream load split 1-to-2 between two directions

*WLAN Parameters*
DS, 11 Mbps channel
buffer size=2.024 Mbits; no fragmentation
RTS/CTS suppressed; max retry limit=7

# QoS-Enhanced MAC

## Priority

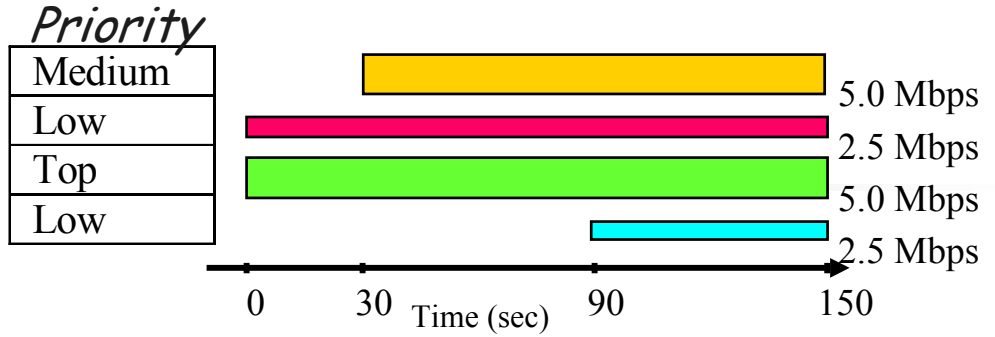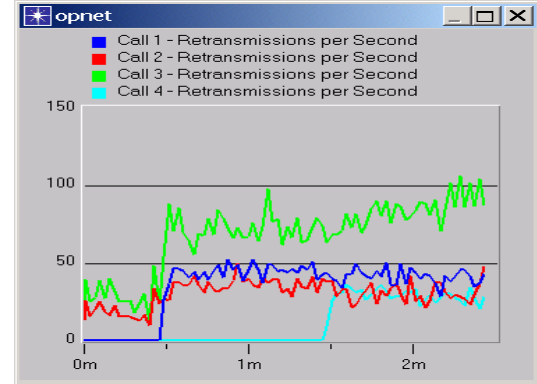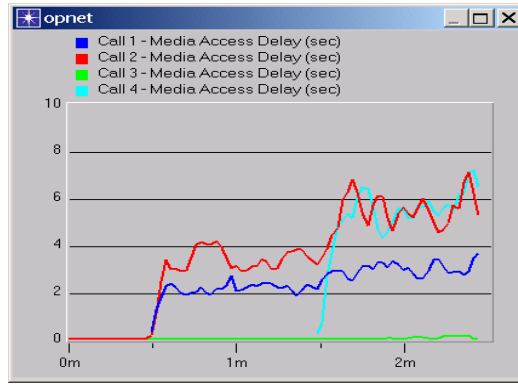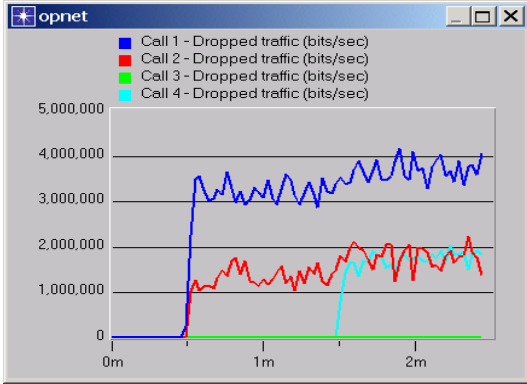| | |
|---|---|
| Medium | 5.0 Mbps |
| Low | 2.5 Mbps |
| Top | 5.0 Mbps |
| Low | 2.5 Mbps |

Time (sec)

0    30    90    150
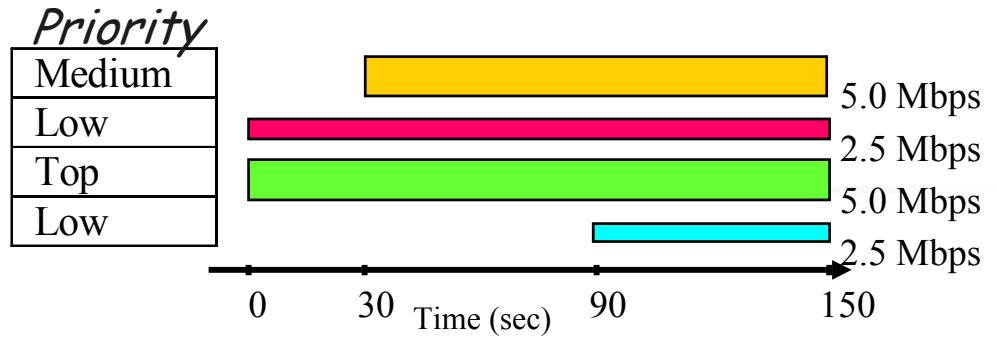
**TCMA**



**V-DCF**

# QoS-Enhanced MAC

*Priority*

| | |
|---|---|
| Medium | |
| Low | |
| Top | |
| Low | |

5.0 Mbps

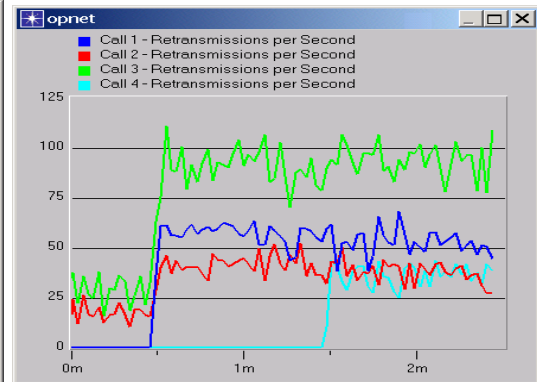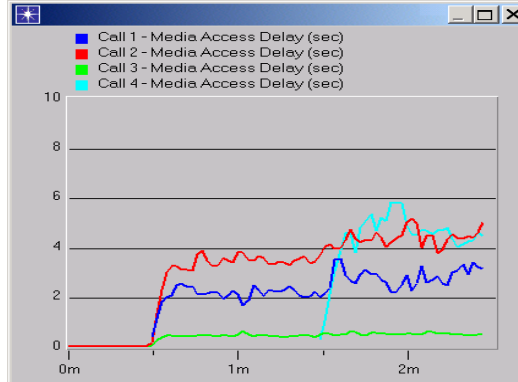2.5 Mbps

5.0 Mbps

2.5 Mbps

0        30    Time (sec)    90        150
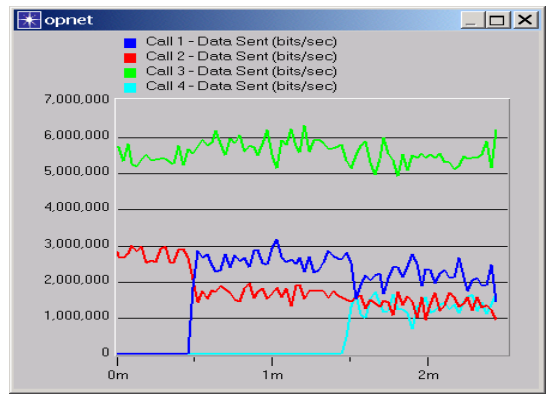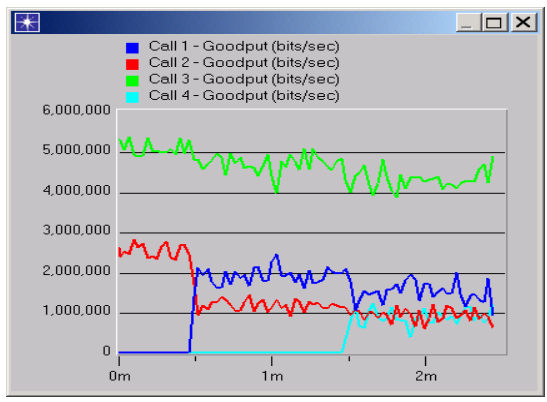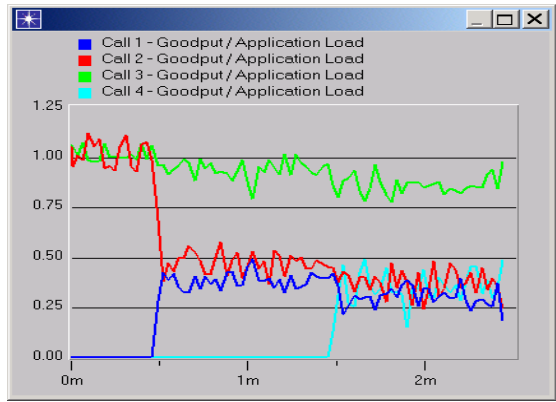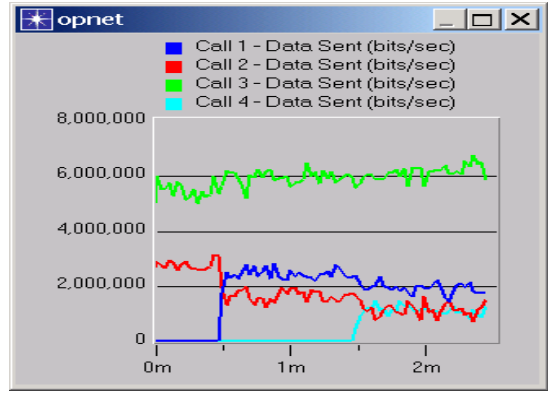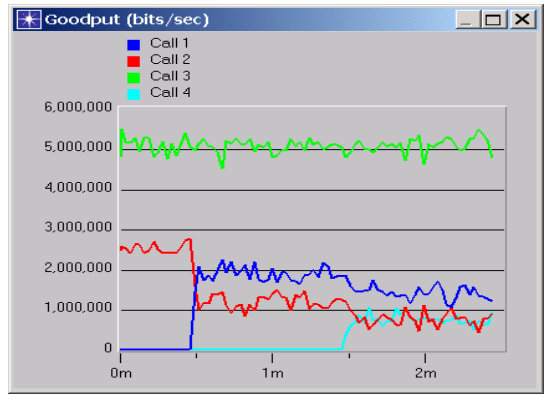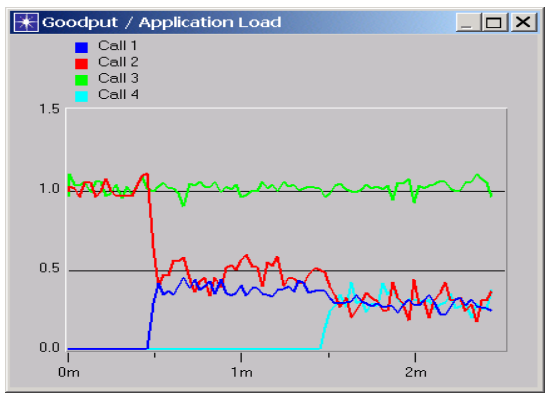
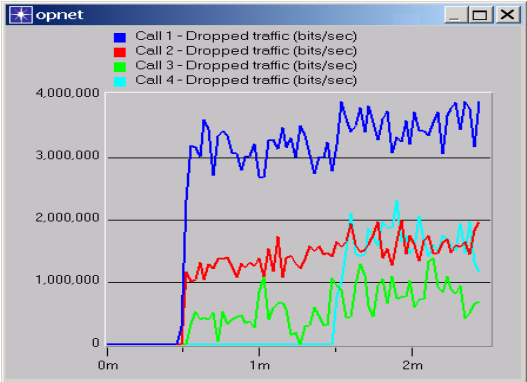**TCMA**



**V-DCF**

# Conclusion

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# Conclusion

- TCMA encompasses the other two proposals, adding more features
  - UATs prevent collisions by packets of different priorities in congestion (high priority goes first)
  - Fewer collisions, greater throughput
  - Reduced delay
- Provides greater flexibility for class differentiation in presence of legacy
- Class upgrades enable better compliance with QoS and fairness objectives