Achieving Service Differentiation and High Utilization in 802.11

Vasilios A. Siris

Inst. of Comp. Science, FORTH & Univ. of Crete
Crete, Greece
vsiris@ics.forth.gr
http://www.ics.forth.gr/netlab

Joint work with Matina Kavouridou

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Problem

- Wireless spectrum a shared & limited resource
- 802.11 MAC does not support differentiation

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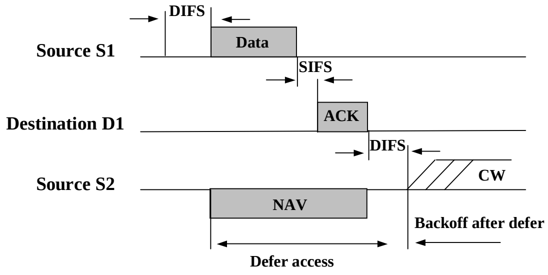
- Approach:
  - 802.11e MAC: Enhanced Distributed Coordination Function (EDCF)
  - Adaptively set parameters of EDCF based on measurements of aggregate throughput

DCF: Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)



- If S1 senses channel idle for DIFS it sends data
  - Else waits for channel to be idle for DIFS and selects random backoff (S2)
- Backoff selected from interval [0,CW-1]
  - CW in [CWmin,CWmax], doubles after collision
- NAV (network allocation vector) used for virtual carrier sensing

Parameters for Service Differentiation

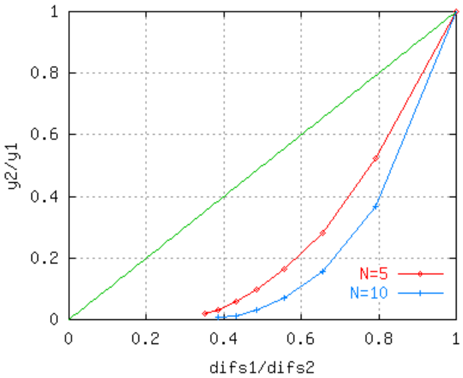
- Frame size
- DIFS (AIFS in 802.11e)
- CWmin
- CWmax
- Persistence Factor (PF): CW increase after collision

} IEEE 802.11e

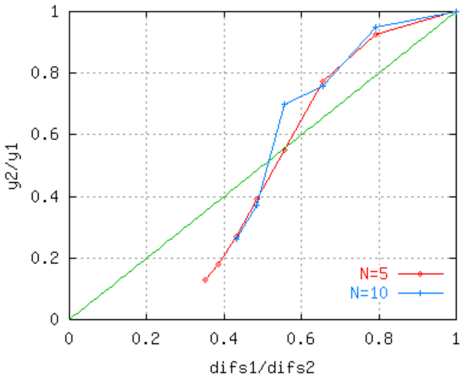
Investigations:

- Metrics: throughput and delay
- Proportional differentiation

DIFS: Throughput differentiation



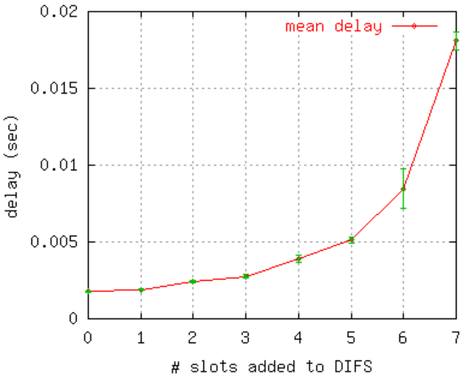
CBR-UDP



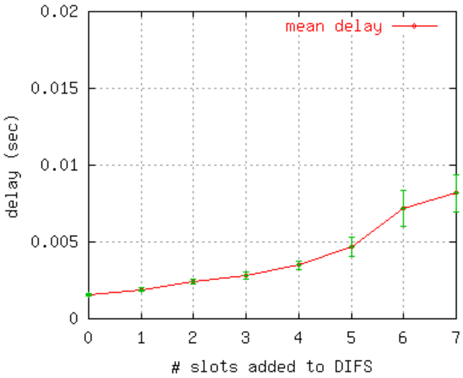
TCP

- 5/10 CBR/TCP sources, 500 bytes pkt
- DIFS differentiation less effective compared to CWmin

DIFS: Delay differentiation



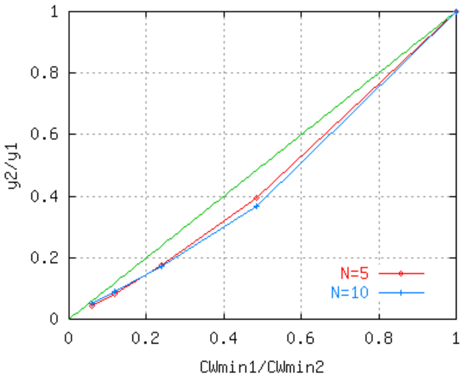
voice-UDP



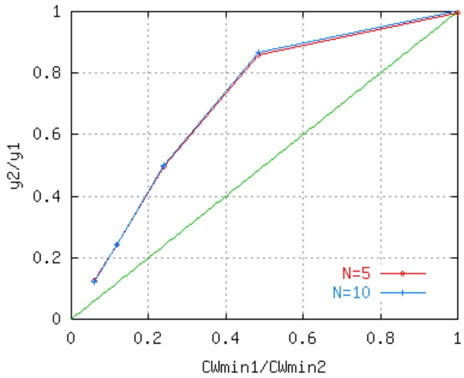
TCP

- 2 voice/TCP, 3 CBR (background), 500 bytes pkt

CWmin: Throughput differentiation



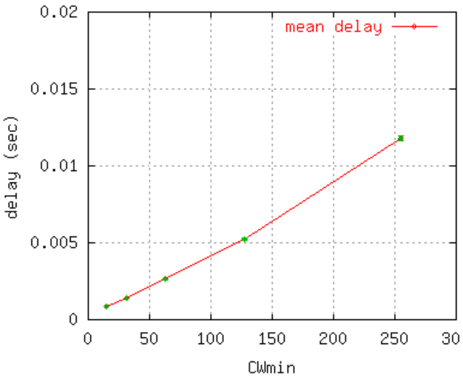
CBR-UDP



TCP

- 5/10 CBR/TCP sources, 500 bytes pkt
- Differentiation less effective for TCP

CWmin: Delay differentiation



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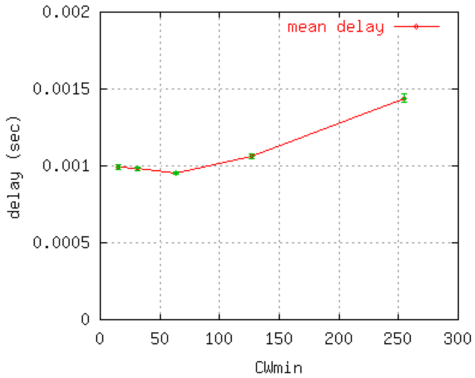


TCP

- 2 voice/TCP, 3 CBR (background), 500 bytes pkt

Observations

- CWmin differentiation closer to proportional sharing compared to DIFS
- Both for throughput and delay differentiation
- Differentiation more effective for UDP, compared to TCP
- But, achievable throughput depends on values of parameters

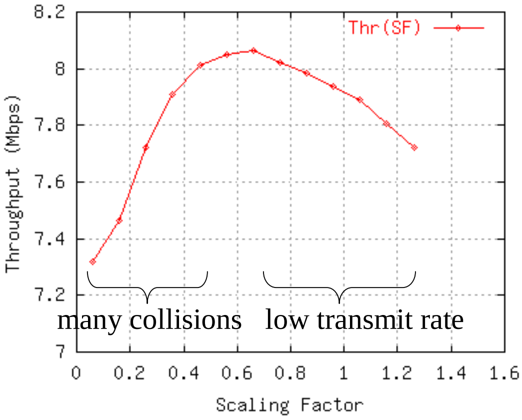
CWmin calculation

- $CWmin_i$ for class I calculated based on weight ϕ_i and frame size L_i

$$CWmin_i = \left\lfloor SF \cdot \frac{L_i}{\varphi_i} \right\rfloor$$

  - SF is a scaling factor
- Optimal values of CWmin (equivalently SF) depend on # of mobiles, traffic, & capacity
- Need to *adaptively* set CWmin

Dependence of throughput on SF



- Above suggests how to search for optimal SF
- Requires only measurements of aggregate throughput

SF update procedure

Step 1: SF_1:=<initial value>

Throughput R_1 measured in interval T_m

Step 2: $SF_2 := SF_1 + \Delta_{SF}$

Step 3: If $R_2 > R_1$ then

SF increases by Δ_{SF} while throughput increases

Else if $R_2 < R_1$ then

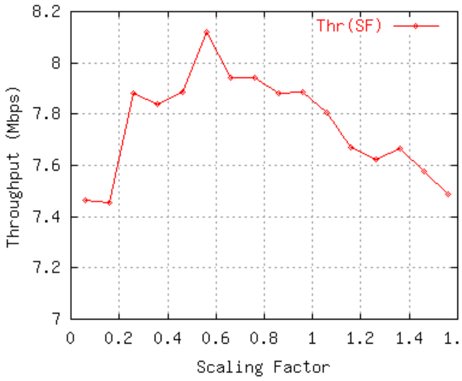
SF decreases by Δ_{SF} while throughput increases

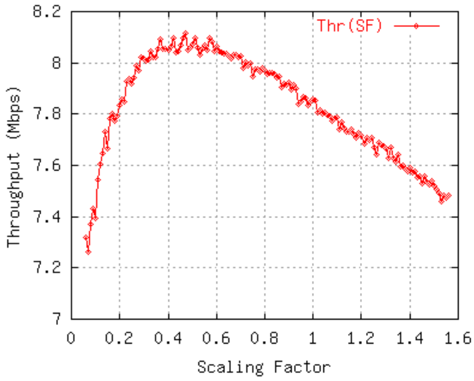
Step 4: Let SF*, R* be the optimal values

If $R_1 < \alpha R^*$ then goto Step 2

Parameters: T_m, Δ_{SF}, α

Effect of tuning parameters

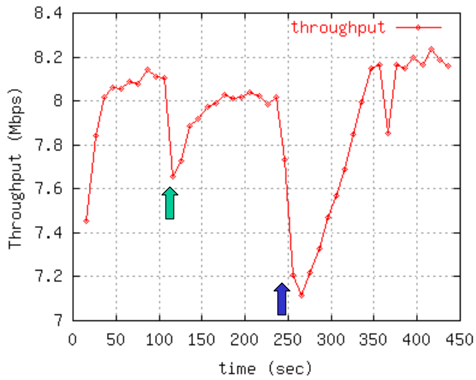




T_m = 1sec, Δ_{SF}=0.1

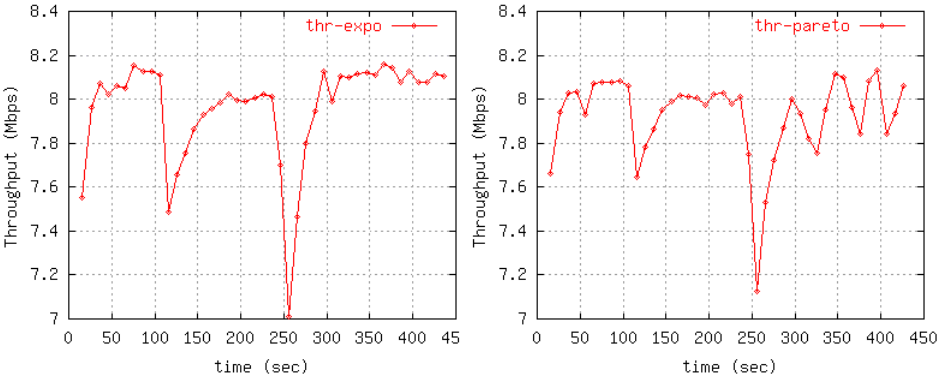
T_m = 10sec, Δ_{SF}=0.01

Reaction to load changes: CBR traffic



- Initially 13 stations with UDP traffic
- 20 more stations enter at time 110 sec
- 23 stations depart at time 240 sec

Reaction to load changes: Exponential and Pareto traffic



Exponential   Pareto

- Exponential: “on”: 800ms, “off”: 200ms, peak: 1 Mbps
- Pareto: “on”: 800ms, “off”: 200ms, peak: 1 Mbps, shape: 1.5

Summary

- Investigation of service differentiation
  - throughput and delay
  - CWmin differentiation appears most flexible
- Optimal values of CWmin depend on # of mobiles, traffic, and capacity
- Procedure for adjusting CWmin, through SF
  - Uses measurements of aggregate utilization
  - Runs at AP
  - No changes at mobiles, if they support 802.11e
  - Issues: communication of CWmin values, update timescale

Related ongoing work

- Approach utilizes MAC layer mechanisms
- Alternative: use IP layer mechanisms at AP
  - Downlink differentiation requires modification only at AP (clients can be 802.11b/a/g)
  - Implementing prototype (Linux-based AP)
- Emerging transport protocols (e.g. DCCP) over 802.11e
- Seamless wired/wireless congestion control using ECN (Explicit Congestion Notification)
  - Economic models for efficient and robust control