Surpassing Flow Fairness in a Mesh Network: How to Ensure Equity among End Users?

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Mesh Fairness: What and Why?

An Example Mesh
(http://www.cnri.dit.ie/research.mesh.congestion.html)

Network Load

Throughput

F1

F2

F1

F2
Mesh Fairness: What and Why?

An Example Mesh
(\url{http://www.cnri.dit.ie/research.mesh.congestion.html})

IEEE 802.11

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Enhanced Distributed Channel Access (EDCA) - The IEEE 802.11 Standard
- Equal air-time fairness

![Diagram showing two flows, F1 and F2, accessing the channel over time.](image)

Time
Mesh Fairness: Benchmark 2

**End-to-end Flow Fairness**

- **Fair Queuing** - difficult for implementation in distributed environment, however provides optimal performance
- Max-min fairness\(^2\) : Maximize the minimum throughput
- Proportional Fairness\(^3\)


\(^3\)Sandip Chakraborty, Pravati Swain, Sukumar Nandi, “Proportional Fairness in MAC Layer Channel Access of IEEE 802.11s EDCA based Wireless Mesh Networks”, Ad Hoc Networks, Elsevier, Volume 11, Issue 1, January 2013, Pages 570584
A Mesh Testbed: Experiment Scenario

- **Router:** **RaLink RT-3352 RoC:** 2T2R MAC/BBP/PA/RF, 400MHz MIPS24KEc CPU, 64MB of SDRAM and 32MB of Flash
- IEEE 802.11g: 6 Mbps, 5 GHz
- Open80211s: [http://www.open80211s.org](http://www.open80211s.org)
- Linux Kernel 2.8.54
- TCP (FTP) and UDP (TFTP) using **iperf** ([http://iperf.sourceforge.net/](http://iperf.sourceforge.net/))
- Semi-indoor environment, Tx Power 16dBm, Rx Sensitivity 0 dBm (45-55 mt in indoor)
UDP Performance

![Diagram of network connections between APs: AP1, AP2, AP3, AP4, AP5, AP6, AP7, GATE.]

- **Average Client Throughput (Kbps)**
  - **MAC with Per-Flow Queuing**
  - **EDCA MAC**

- **Data Delivery Rate (Mbps)**
  - **MAC with Per-Flow Queuing**
  - **EDCA MAC**

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TCP Performance

![Network Diagram]

![Bar Charts]

**Average Client Throughput (Kbps)**

**Average Retransmission Timeout**

- **MAC with Per-Flow Queuing**
- **EDCA MAC**

**Router Number**

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Mesh Performance: Few More Results

MAC with Per-flow Queuing

EDCA MAC

Jain Fairness Index

Backlog Data (Kb)

Time of the Day (Hrs)

Time of the Day (Hrs)

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What We Observe?

- MAC layer flow coordination is not necessarily coordinated by transport layer flow controls
  - wireless channel quality fluctuations,
  - Aggregation of different flows at intermediate routers

- Failure of transport layer fairness control → Problems with backlog data (data loss from interface queues)

- MAC layer coordination is necessary for fairness

- Backlog data at mesh routers need to be minimized (similar for all the routers in the neighborhood)
A Method for MAC Coordination

- Required Channel Share (RS) is estimated based on forwarding traffic load,

\[ RS = \frac{\text{Traffic load of this router}}{\text{Traffic load of neighbors}} \]

Forwarding traffic load → Backlogged traffic load
A Method for MAC Coordination

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Forwarding traffic load → Backlogged traffic load

![Diagram](image)

- DATA||TAF\_s

- ACK||TAF\_D
A Method for MAC Coordination

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Forwarding traffic load → Backlogged traffic load

- Actual Channel Share is the ratio of actual traffic (number of packets transmitted or received) to the overhead traffic (number of packets overheard in promiscuous mode)
On Tuning EDCA Congestion Window

\[ P_{AN} = \frac{t_A}{t_A + t_N}; \]
\[ P_{AA} = 1 - P_{AN}; \]
\[ P_{RN} = \frac{t_R}{t_N + t_R}; \]
\[ P_{RR} = 1 - P_{RN}; \]
\[ P_{NA} = \frac{t_N}{t_A + t_N + t_R}; \]
\[ P_{NR} = \frac{t_N}{t_A + t_N + t_R}; \]
\[ P_{NN} = 1 - P_{NA} - P_{NR}; \]
On Tuning EDCA Congestion Window

Transition $u \rightarrow v$

\[ P_{uv} \times AF_{ic} > P_{uu} \times AF_{iu} \]

where,

$AF_{ic}$ is the current AF value for router $i$

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Performance: 8 Node Testbed

MAC with Per-Flow Queuing
Proportional Fairness [8]
Improved Proportional MAC

Average Client Throughput (Kbps)

Router Number

Time of the Day (Hrs)
Performance: 8 Node Testbed

AP2  AP3  AP5  AP7
AP1  AP4  AP6
GATE

MAC with Per-flow Queuing
Proportional Fairness [8]
Improved Proportional MAC

Jain fairness Index

Time of the Day (Hrs)
- Supports 2 Mbps at long communication range
- Complex flow scenario
Performance: 11 Node Testbed

MAC with Per-Flow Queuing
Proportional Fairness [8]
Improved Proportional MAC

Average Client Throughput (Kbps)

MAC with Per-flow Queuing
Proportional Fairness [8]
Improved Proportional MAC

Average Client Throughput (Kbps)

Time of the Day (Hrs)
Performance: 11 Node Testbed

- AP1
- AP2
- AP3
- AP4
- AP5
- AP6
- AP7
- AP8
- AP9
- AP10

MAC with Per-flow Queuing
- Jain fairness Index
  - Time of the Day (Hrs)

- Improved Proportional MAC
  - Proportional Fairness [8]
Conclusion with Some Comments

- Fairness problem is severe, and roots in the MAC layer
- A scheme has been proposed with evaluation in real testbed
  - Distributed as well as localized
  - Less control overhead (piggybacking)
  - Scalable (fast converge)
  - Avoids flapping during parameter tuning (a major problem in existing solutions)
- This paper has considered IEEE 802.11g and low data rates. The experiments are also conducted with IEEE 802.11n high data rates, in a more complex topology (Papers are accepted for presentation in COMSNETS 2014, to be held in Bangalore, India in January, 2014)
  - Similar fairness problems are observed with some additional ones (severe hidden terminals, route flapping)
  - The proposed scheme works in high data rates up to some level, however, additional cares are required
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Thank You