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SoftMAC Layer 2.5 Collaborative MAC for Multimedia Support in Multihop Wireless Networks

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Outline

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- SOFTMAC ARCHITECTURE
- KEY MODULES IN SOFTMAC
- SIMULATION AND EXPERIMENT RESULTS
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Introduction

- IEEE 802.11(in DCF—distributed coordination function—mode) employs CSMA/CA-based media access control (MAC) to reduce collisions. It works well in wireless LAN (WLAN), **but poorly in multihop wireless networks**, where collisions happen because the transmitters are out of each other's carrier sense range.

Introduction

- Although a QoS-enhanced 802.11e MAC mechanism, eDCF, has been developed for WLAN, but it does not provide adequate service differentiation for the support of RT traffic in multihop wireless networks because of the hidden terminal and other interference problems.
- However, there are several challenges in effectively realizing RT services over multihop wireless networks

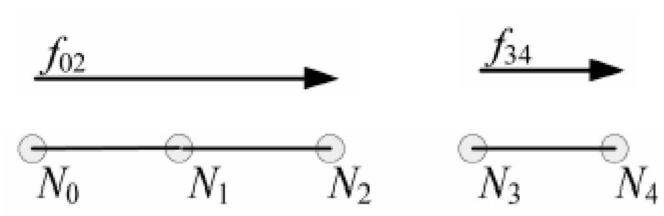
Introduction

- This paper presents the challenges in supporting multimedia, in particular, VoIP services over multihop wireless networks using commercial IEEE 802.11 MAC DCF hardware, and propose a novel software solution, called Layer 2.5 SoftMAC

CHALLENGES IN VOIP SERVICES SUPPORT

Packet size:1000bytes
Rate: 250packets/s
End-to-end delay: 356ms
End-to-end loss rate: 43.8 percent

Packet size:1000bytes
Rate: 250packets/s
End-to-end delay: about 1.3ms
End-to-end loss rate: 0 percent

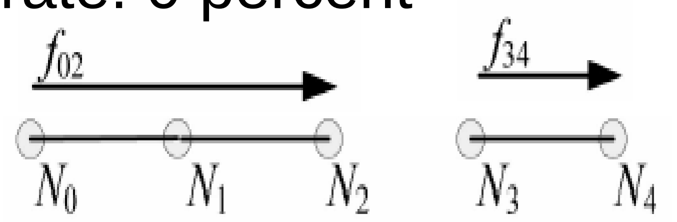


After $f_{(0,2)}$
End-to-end delay: 14ms
End-to-end loss rate: 0 percent

CHALLENGES IN VOIP SERVICES SUPPORT

RT flow
Packet size:50 bytes
Rate: 100 packets/s
End-to-end delay: 1.6ms
End-to-end loss rate: 0 percent

After BE flow (rate is 250 packets/s)
End-to-end delay: 18ms
End-to-end loss rate: 0 percent



BE flow
Packet size:1500bytes

After BE flow (rate is 330 packets/s)
End-to-end delay: 547ms
End-to-end loss rate: 38.2 percent

SOFTMAC ARCHITECTURE

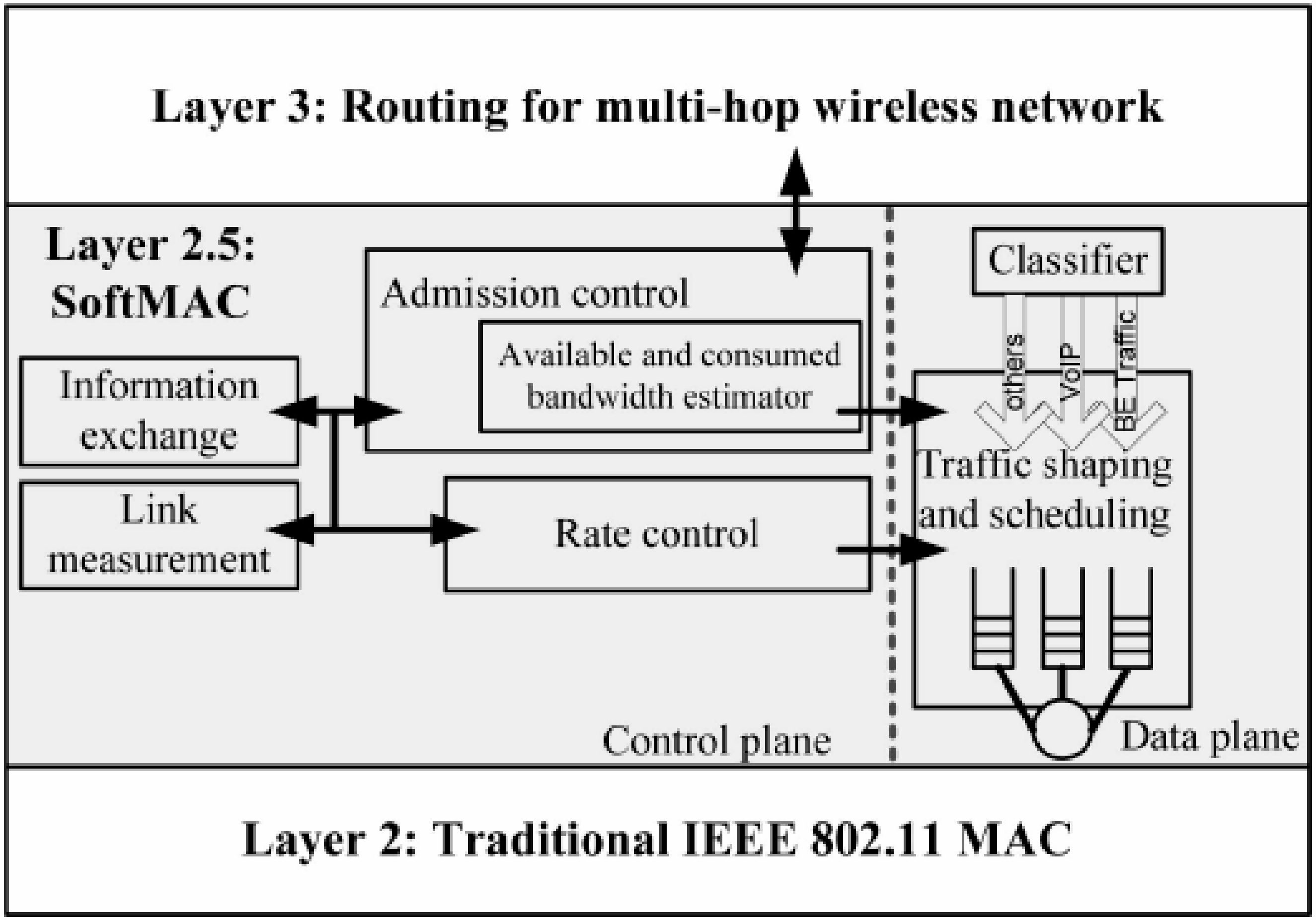


Fig. 2. SoftMAC architecture and components for VoIP.

FRACTION OF AIR TIME (FAT)

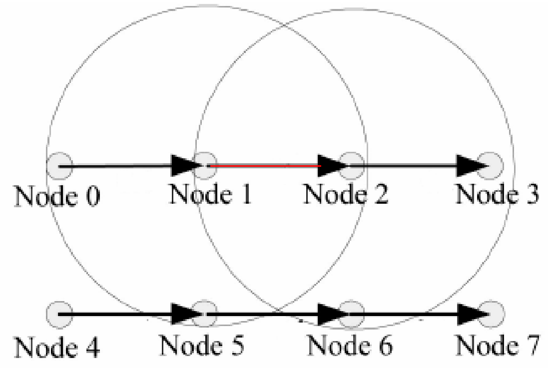
- The admission control and rate control in SoftMAC require a quantified metric to denote consumed/allocated and residual resources.
- The consumed FAT (of the VoIP flow) at link $l_{(i,j)}$ is simply:

$$r_{(i,j),RT} = t_{(i,j),PL} / t_{\text{int}}$$

FRACTION OF AIR TIME (FAT)

- we define the nominal residual FAT of node k, $nrFAT_{k,RT}$, as follows:

$$nrFAT_{k,RT} = \max\left\{0, 1 - \sum_{m \in N(k) or\ n \in N(k)} r_{(m,n),RT}\right\}$$



- we define the residual FAT of node k, $rFAT_{k,RT}$, to be the minimum among node k and its neighbors

$$rFAT_{k,RT} = \min(mrFAT_{k,RT}, mrFAT_{h,RT}), \forall h \in N(k)$$

FRACTION OF AIR TIME (FAT)

- Given the above two notions, we can now define the residual FAT of link $l_{(i,j)}$ to be

$$rFAT_{(i,j),RT} = \min\{rFAT_{i,RT}, rFAT_{j,RT}\}$$

Example

$$nrFAT_{1,RT} = 1 - r_{(0,1),RT} - r_{(2,3),RT} - r_{(4,5),RT} - r_{(5,6),RT} = 0.6$$

$$nrFAT_{2,RT} = 0.6$$

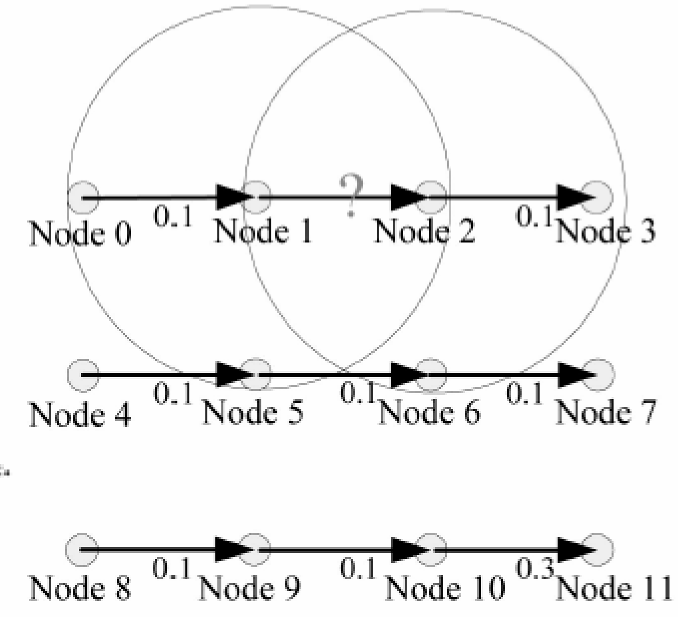
$$nrFAT_{5,RT} = 0.4$$

$$nrFAT_{0,RT} = 0.7$$

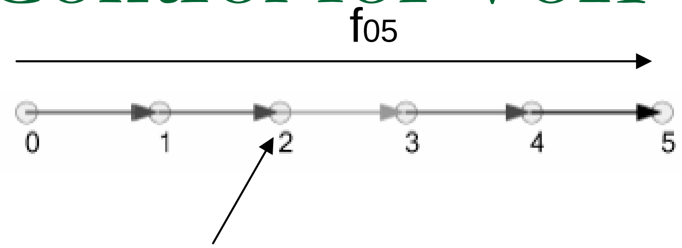
$$rFAT_{1,RT} = \min(mrFAT_{1,RT}, mrFAT_{0,RT}, mrFAT_{2,RT}, mrFAT_{5,RT}) = 0.4.$$

$$rFAT_{2,RT} = 0.2.$$

$$rFAT_{(1,2),RT} = \min(rFAT_{1,RT}, rFAT_{2,RT}) = 0.2$$



KEY MODULES IN SOFTMAC
Admission Control for VoIP Traffic



- Node 2 estimates its total consumed FAT of the new flow on $l_{(2,3)}$, it should take into account the interference of packet transmission from the same flow on the three adjacent links, $l_{(0,1)}$, $l_{(1,2)}$, and $l_{(3,4)}$.

Admission Control for VoIP Traffic

- The total consumed FAT in advance of flow f on link $l_{(i,j)}$, denoted by $TCFAT_{(i,j),f}$ is given by

$$TCFAT_{(i,j),f} = \sum_{m \in N(i) or\ n \in N(i)} CFAT_{(m,n),f}, l_{(i,j)} \in f, l_{(m,n)} \in f$$

- So, node i checks whether $TCFAT_{(i,j),f} \leq rFAT_{(i,j),RT}$ is satisfied.

KEY MODULES IN SOFTMAC

Rate Control for BE Traffic

- The function of rate control is to allocate the residual FAT left by the existing RT traffic (as well as the newly admitted RT one) to BE traffic in a distributed way.

Rate Control for BE Traffic

- Formally, we assign a BE weight, denoted by $w_{(i,j),BE}$ to each link, which satisfies

$$nrFAT_{i,RT} \geq \delta_i \sum_{m \in N(i) \text{or } n \in N(i)} w_{(m,n),BE}$$

- Where δ_i denotes the normalized bandwidth per unit weight. Therefore, we have

$$\delta_{i,\max} = nrFAT_{i,RT} / \sum_{m \in N(i) \text{or } n \in N(i)} w_{(m,n),BE}$$

Rate Control for BE Traffic

- Each node i will broadcast $\delta_{i,\max}$ to control the BE traffic to minimize interference with the RT traffic.
- The consumed FAT for BE traffic at link $l_{(i,j)}$ is then controlled by using the minimal $\delta_{i,\max}$ received value

$$r_{(i,j),BE} = \min(\delta_{k,\max}, \delta_{l,\max}) \times w_{(i,j),BE}, \forall k \in N(i), l \in N(j)$$

SIMULATION AND EXPERIMENT RESULTS

In total, 24 VoIP flows are generated and injected into the network one by one every 4 seconds starting from second 24.

Data rate : 50 frame/s

The payload per frame generated by the codec is 33 bytes. Including the 12 byte application header, 8 byte UDP header, and 20 byte IP header, the total payload per frame is 73 bytes.

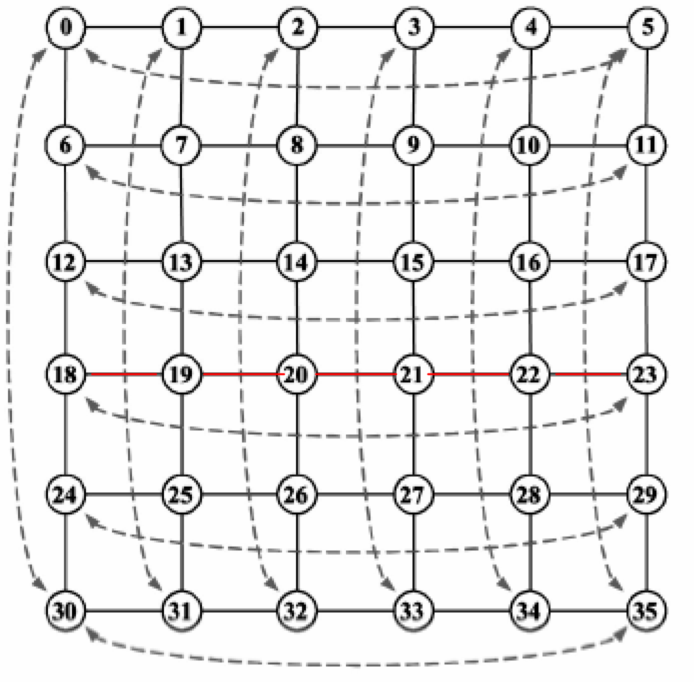
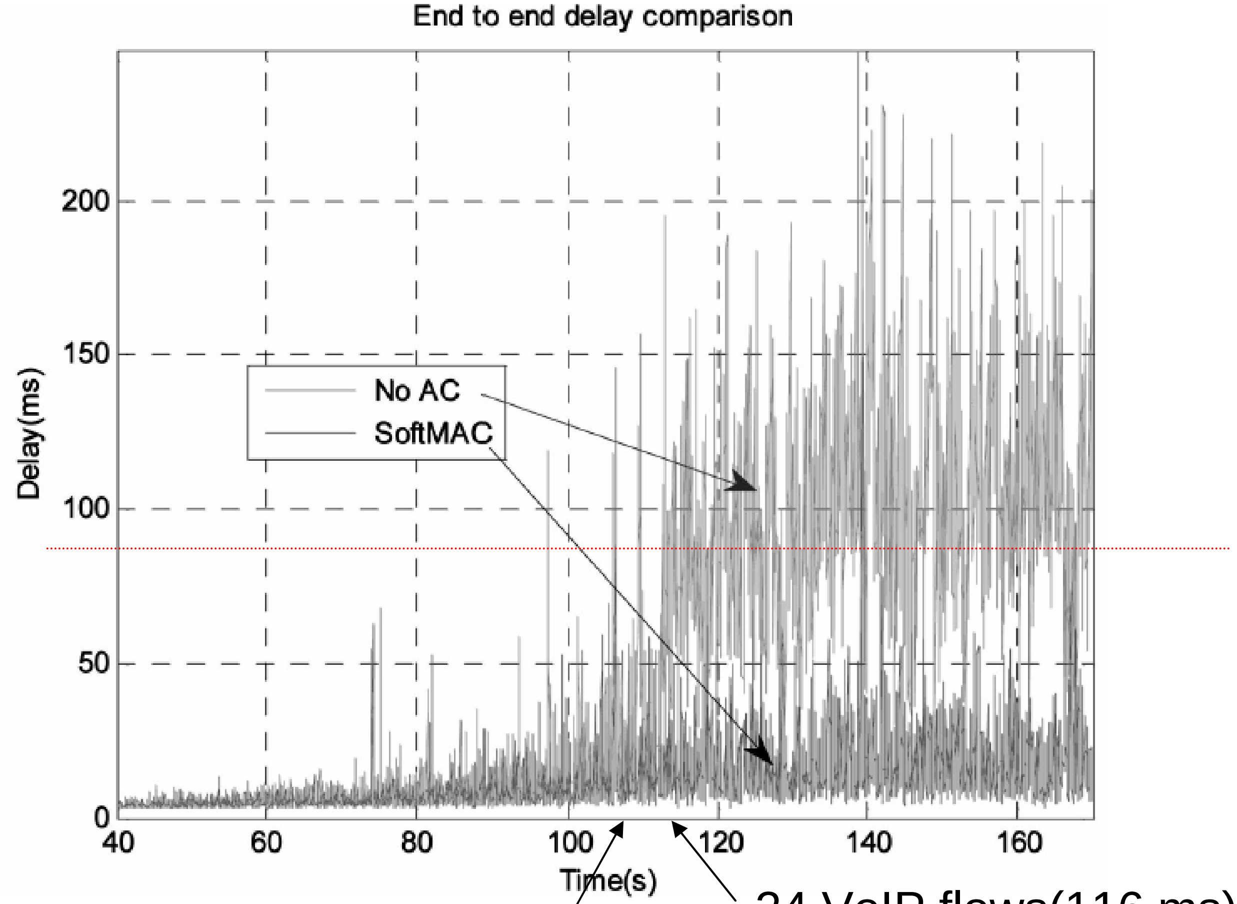


Fig. 7. Grid topology and traffic pattern

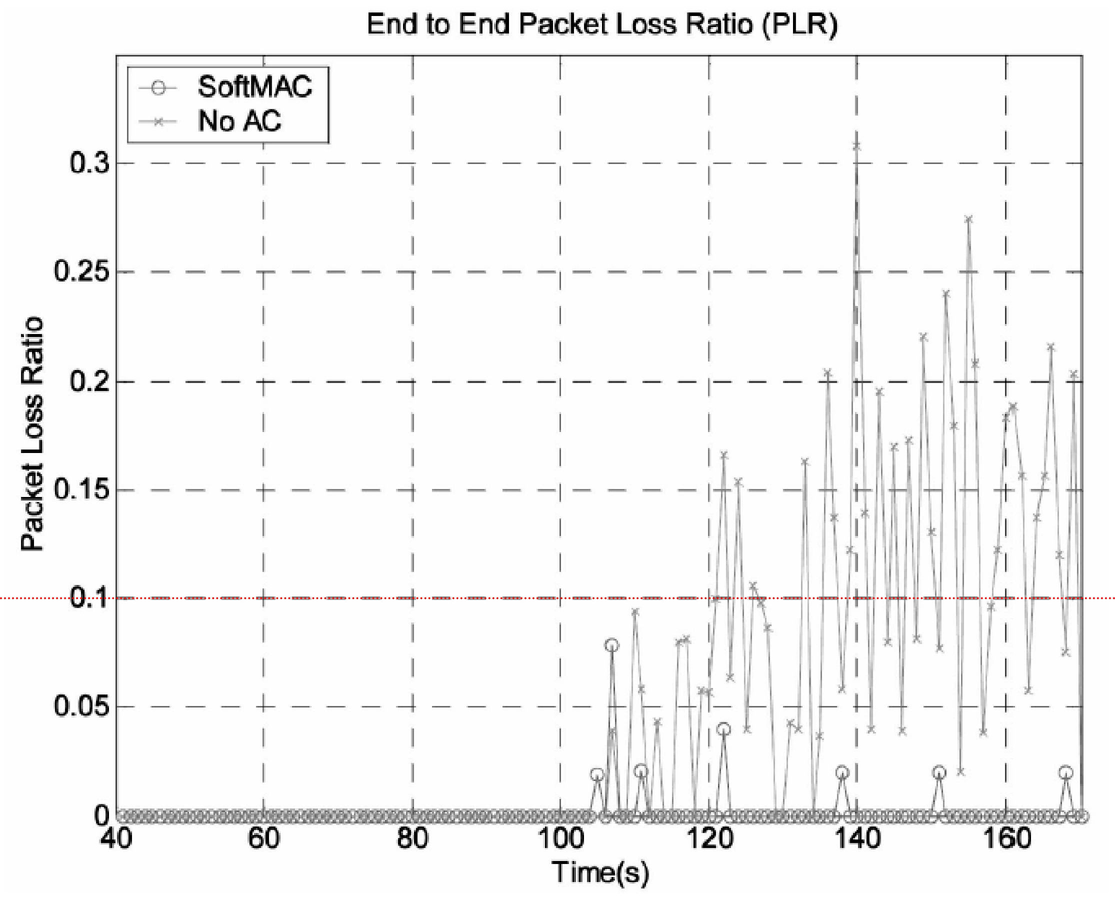
End-to-end delay comparison



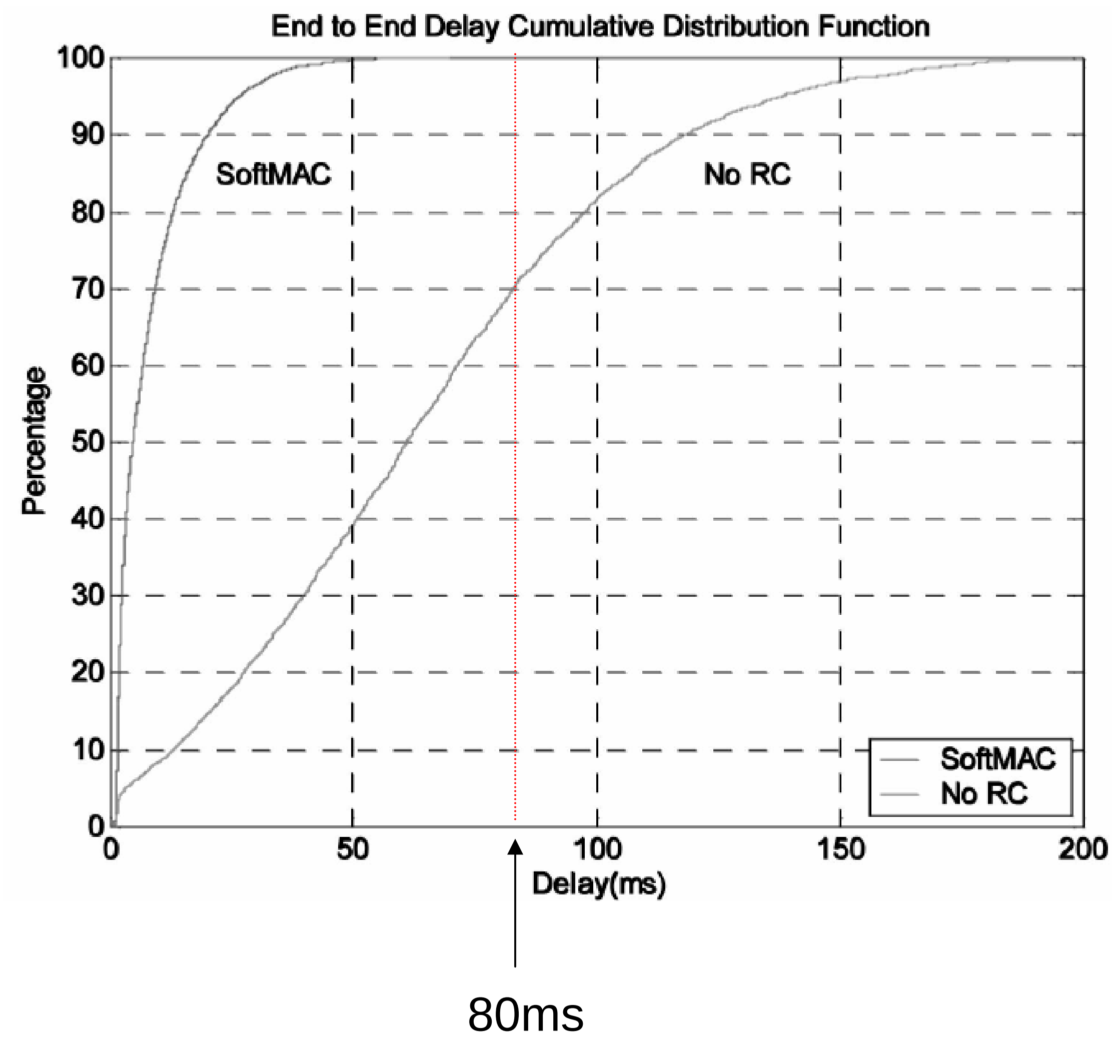
24 VoIP flows(116 ms)

with SoftMAC AC, only 22 VoIP flows are accepted

Packet loss ratio comparison

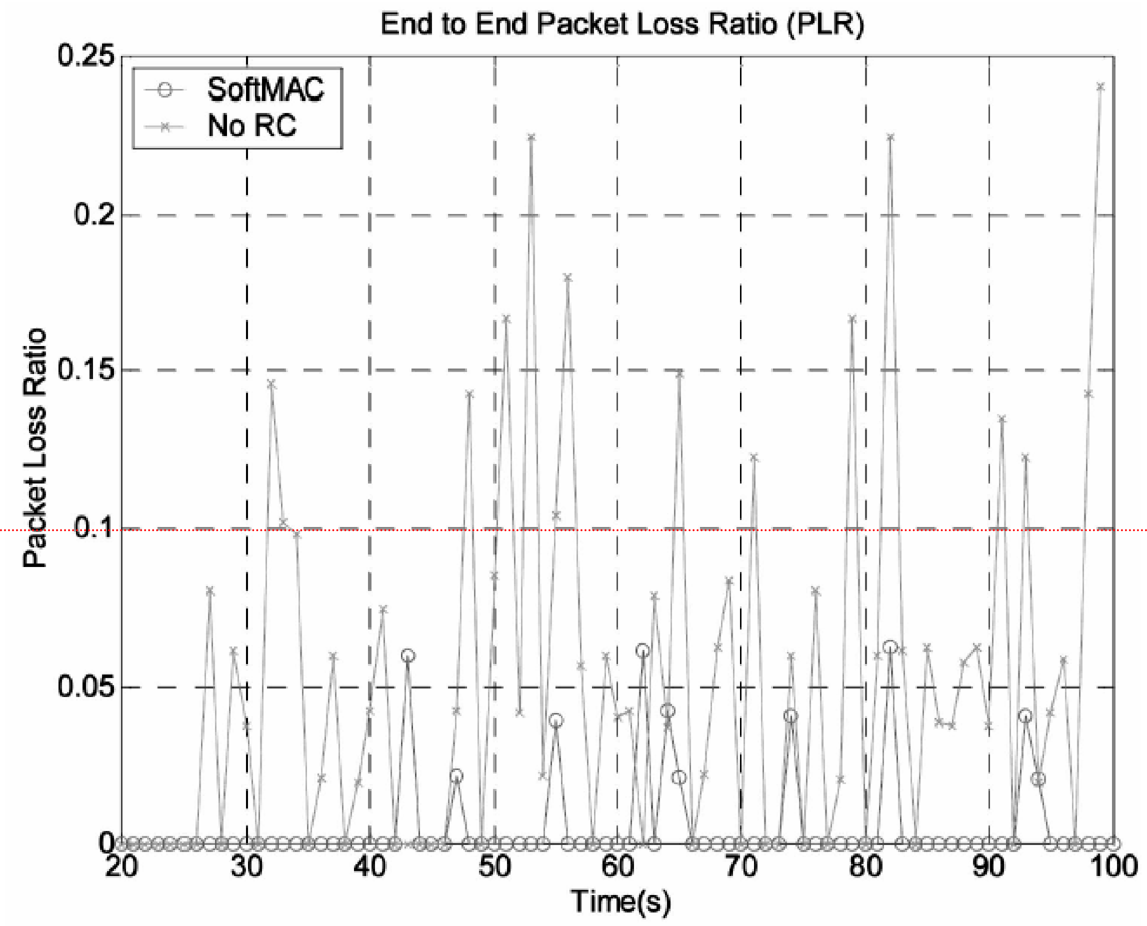


End-to-end delay of VoIP

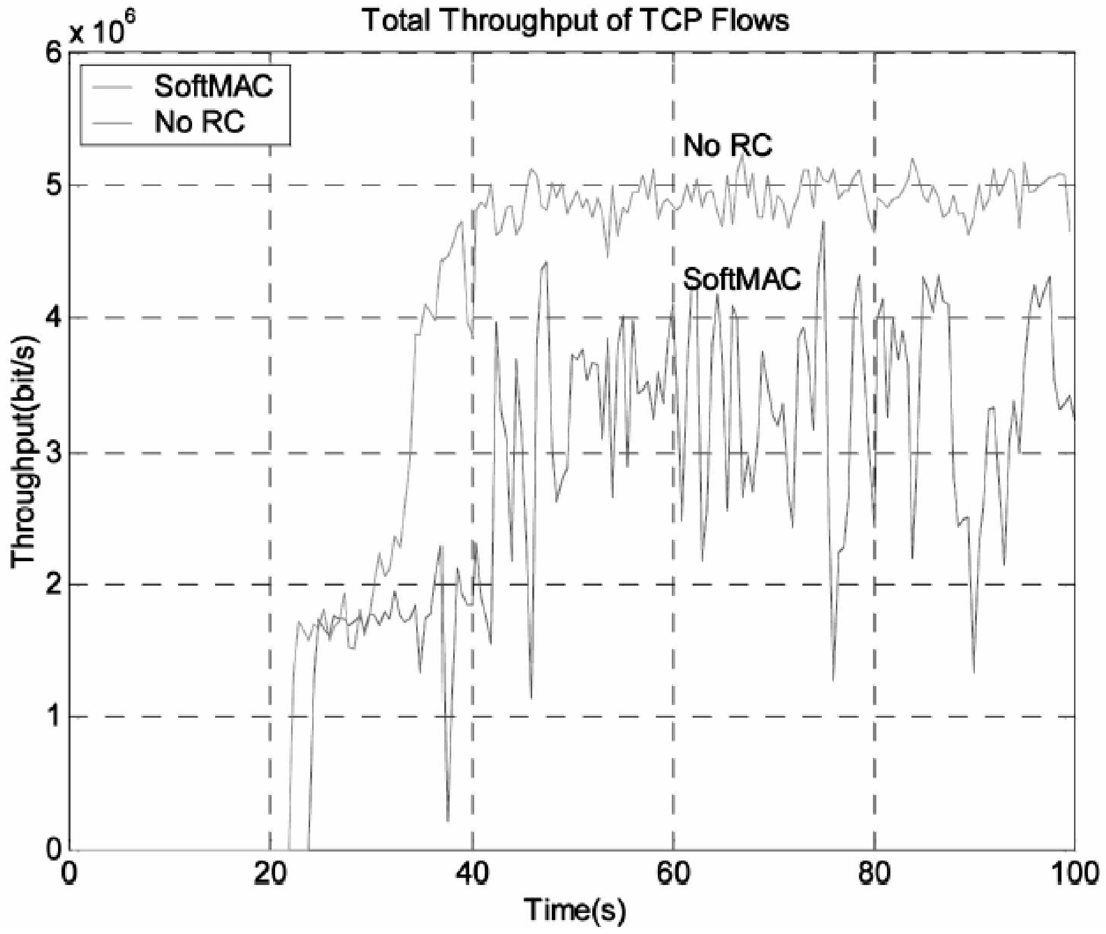


inject 3 VoIP flows(f0,5, f12,17, f24,29) , 12 BE flows(every 2 seconds into the network)

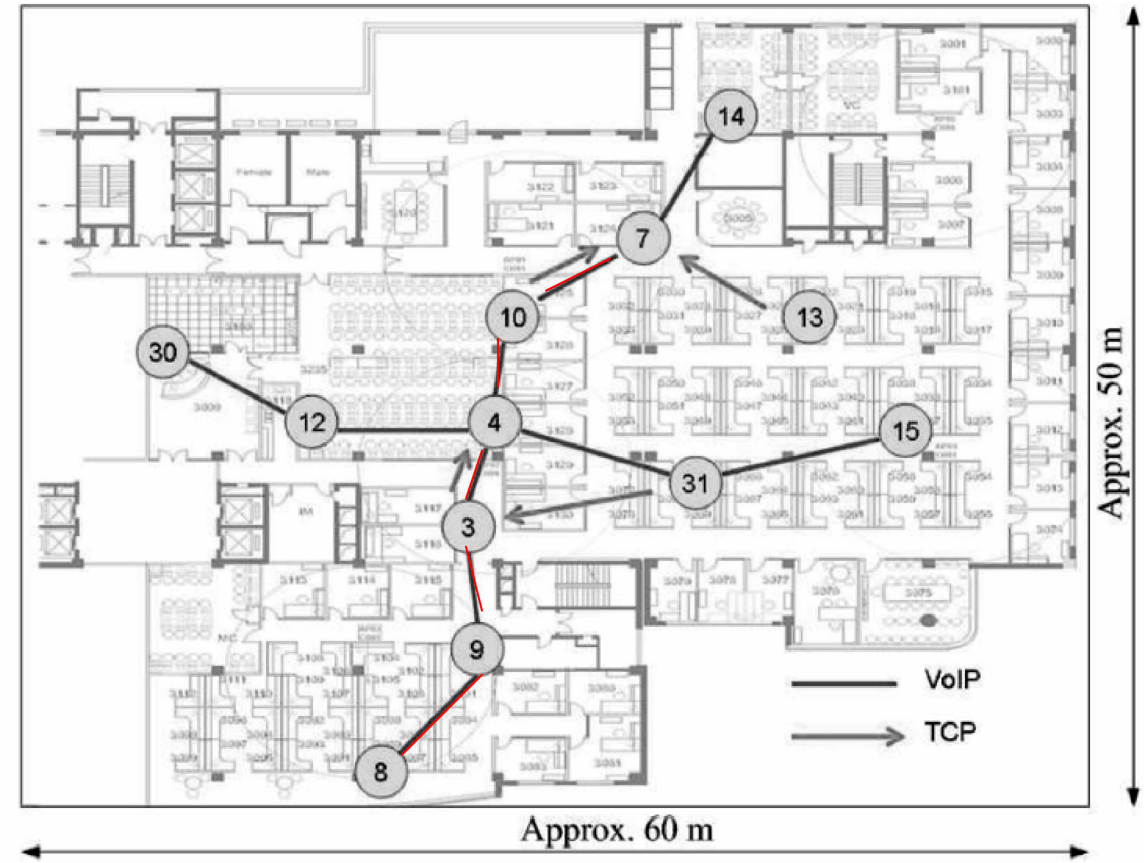
End-to-end packet loss ratio of VoIP



Total throughput of TCP

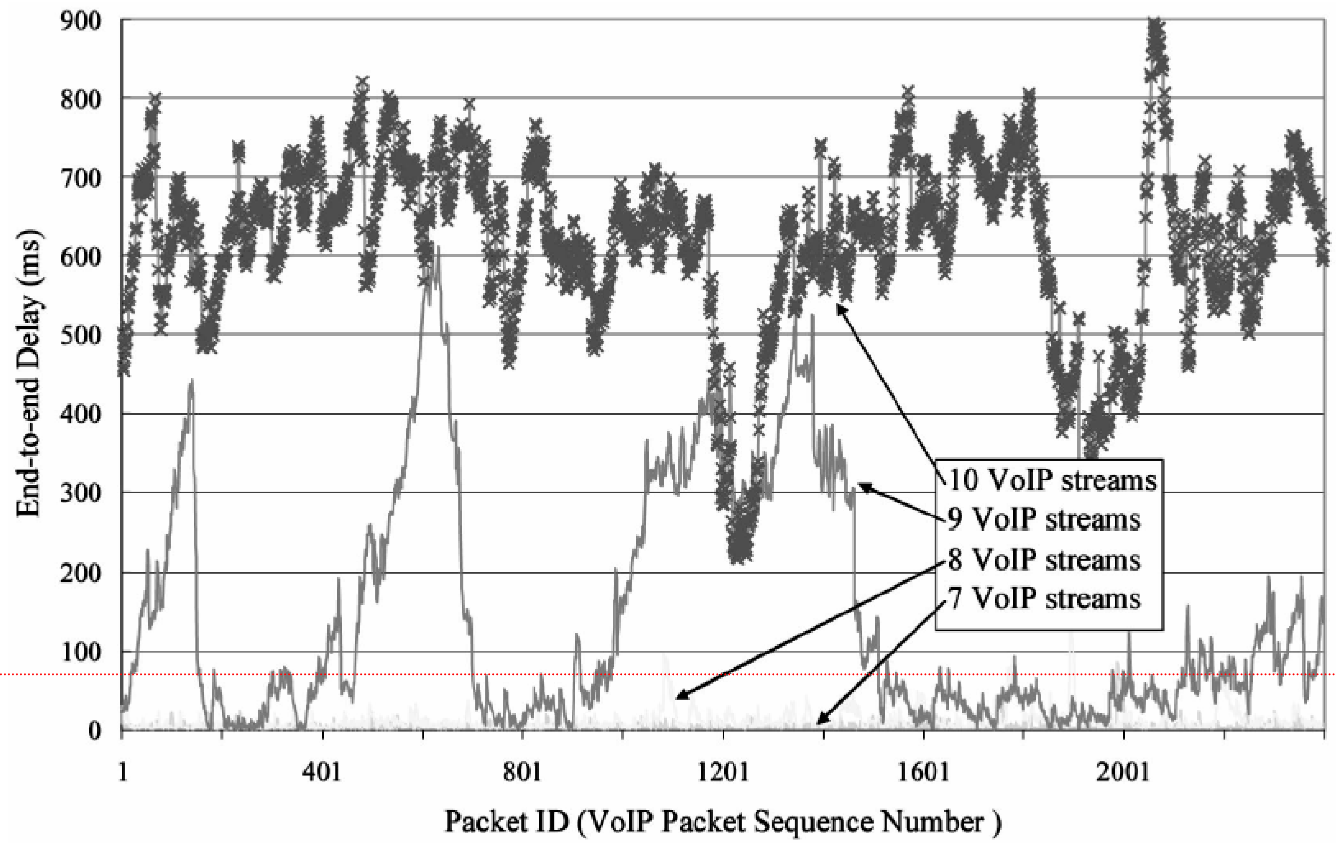


Experiment topology



All the VoIP flows are generated between node 7 and node 8 along the path.

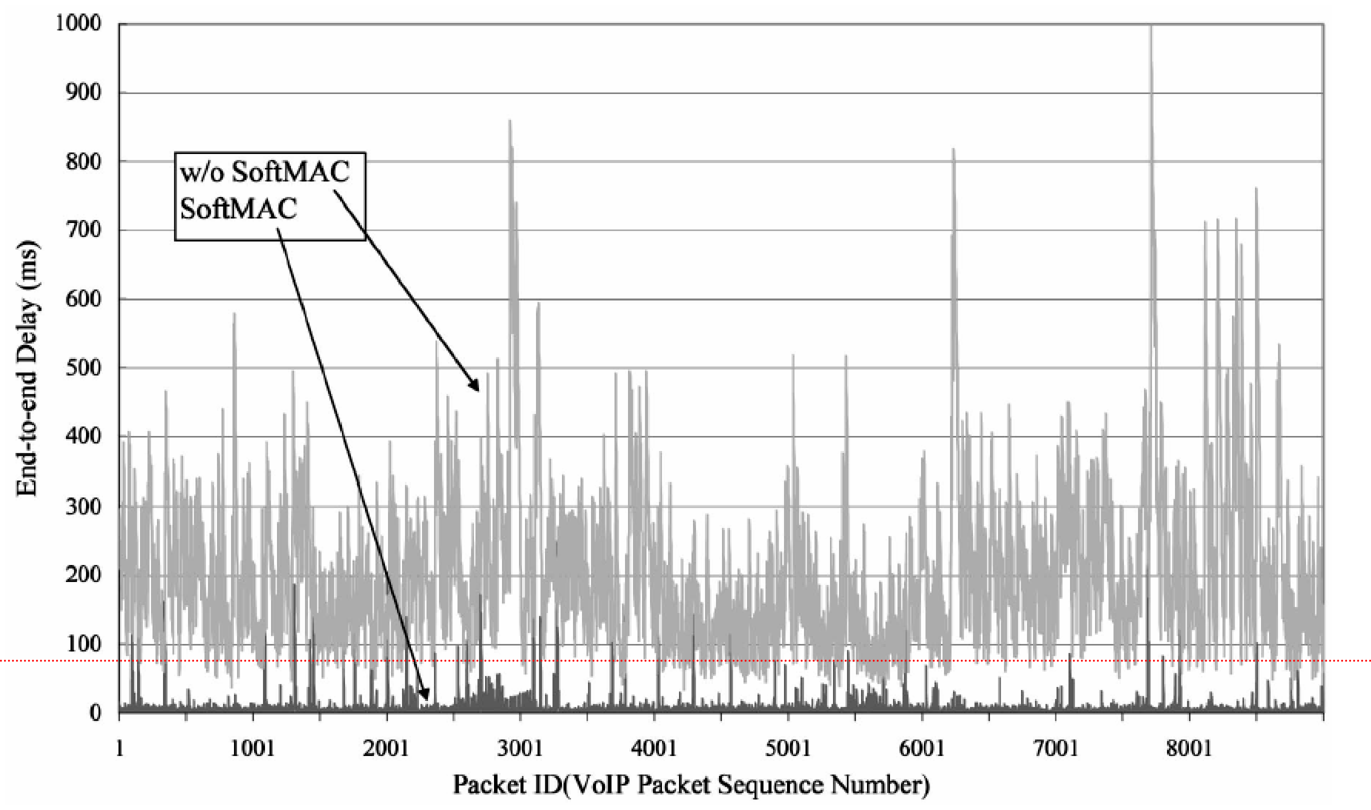
End-to-end delay comparison for AC



With AC disabled, collect the results for 7 10 VoIP flows Concurrently running.

With AC enabled, only seven VoIP flows are accepted

End-to-end delay comparison for RC



Two VoIP flows are set up on path 30-12-4-31-15 and path 9-3-4-10-7-14. Four TCP flows, f(3, 4), f(10, 7), f(31, 3), and f(13, 7) are added as best-effort traffic.

Conclusion

- This paper proposed and presented a novel software solution, called Layer 2.5 SoftMAC, to effectively support VoIP service in multihop wireless networks using commercial IEEE 802.11 MAC DCF hardware.
- Through extensive simulations using the network simulator NS2 and experimental testing on the testbed to demonstrate the efficacy of proposed software solution.