Performance Evaluation and Design Improvement of Media Access Control Protocols for Broadband Wireless Local Loop

Mihir Thaker
Masters Thesis Presentation
Department of Electrical Engineering and Computer Science
University of Kansas
July 19, 2000

Defense Committee: Dr. James Roberts, Chair
Dr. Joseph Evans
Dr. Victor Frost

Organization

- Introduction
- Motivation
- Performance Evaluation
- Design Improvements & Re-evaluation
- Conclusions & Future Work

Introduction

Introduction - Broadband Wireless Local Loop (B-WLL)

- Global demand for high speed Internet access.
- Need for a cost effective and viable solution for the “last mile” problem.
- Fixed wireless access system addresses this problem.
- Restrictions eased for MMDS, MDS and U-NII bands.
- Faster deployment, lower construction, operating and maintenance cost.
- Deployment as a two way point to multi-point system.

Introduction - Media Access Control (MAC) Protocols

- Channel allocation schemes that control the usage of a shared resource and possess desirable performance characteristics.
- In a wireless system, available bandwidth is a resource shared by a large user population.
- TDMA, FDMA and CDMA are popular access schemes.
- Two currently used schemes,
  - Reservation TDMA (R-TDMA), a variation of the TDMA scheme.
  - Multi Frequency Polling (MF-Polling), a variation of the FDMA scheme.
- Desirable performance characteristics
  - High aggregate throughput
  - Low average queuing delay
  - Support a large user population

Introduction - Reservation TDMA (R-TDMA)

- Slot-on-demand TDMA system.
- Request can be made by,
  - Contention (Slotted ALOHA with Exponential Backoff)
  - Piggybacking
- Frame structure is repetitive and is time division duplexed in nature.
- Contention slots varied according to collision conditions.
- Higher slot occupancy per frame implies greater frame efficiency.
- System is thus adaptable to varying traffic conditions.

Introduction - Multi Frequency Polling (MF-Polling)

- Symmetric division of available bandwidth.
- FDM in upstream.
- Polling effective on each channel when the number of users on the channel exceeds one.
- Polling cycle time of 30 ms.
- Inactivity timeouts associated with each user in system.
- Polling ratio decides the maximum number of users per channel.
- Exponential backoff with a maximum window size of 1024, similar to Ethernet.

Motivation

Motivation

- Problem
  - How to choose an appropriate MAC protocol?
  - Given a MAC protocol, how can we improve its performance ?

- Solution
  - Performance evaluation based on HTTP and FTP applications for various load conditions.
  - Identified the contention delay component of average queuing delay as a parameter for improvement
  - Design Improvement
    - Maintain the number of contention slots as constant for each frame in the R-TDMA system.
    - Reduction of maximum window size for the MF-Polling system.

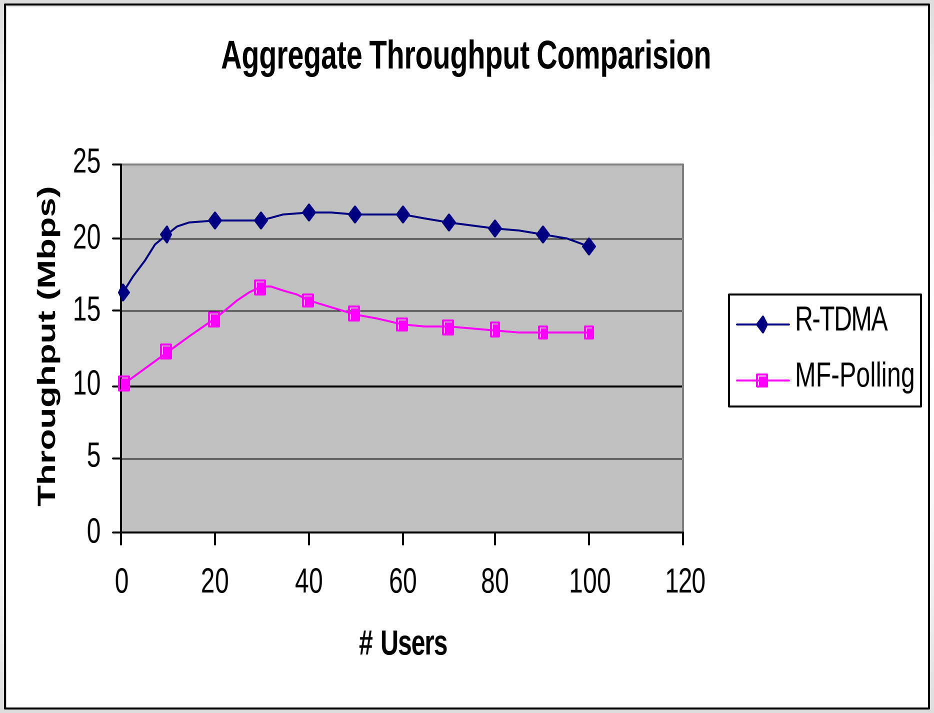
Performance Evaluation

Performance Evaluation

- Test Scenarios
  - Packet Generator Test
    - To measure the performance bound of the protocols.
  - FTP Tests
    - FTP Low Download
      - 1 file/hr, 10,000 bytes/file
    - FTP High Download
      - 10 files/hr, 100,000 bytes/file
  - HTTP Tests
    - HTTP Light Browsing
      - 5 pages/hr, 10 objects/page, 12000 bytes/object
    - HTTP Heavy Browsing
      - 60 pages/hr, 10 objects/page, 12000 bytes/object
  - Medium Load Test
    - FTP Low Download and HTTP Light Browsing
  - Load conditions suggested by OPNET™.

Packet Generator Test

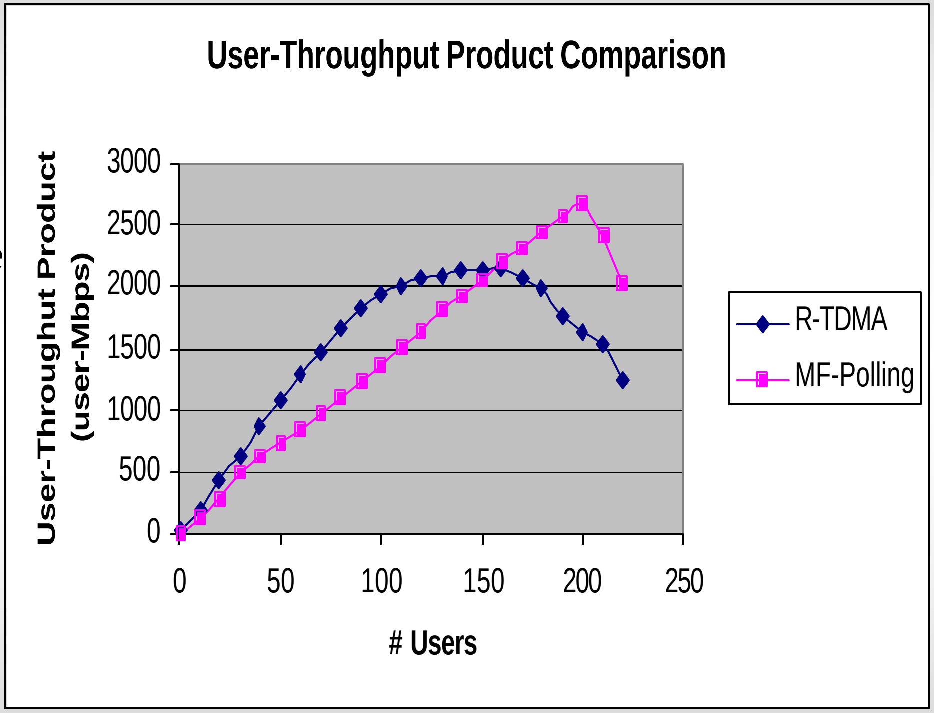
- Shows the upper bound on the system performance.
- Available bandwidth 12.5 MHz, QPSK modulation.
- Tested using a packet generator with inter-arrival rate marginally greater than the link rate.
- R-TDMA shows better performance than MF-Polling. However, throughput gradually decreases with increase in the number of users.



Packet Generator Test (cont...)

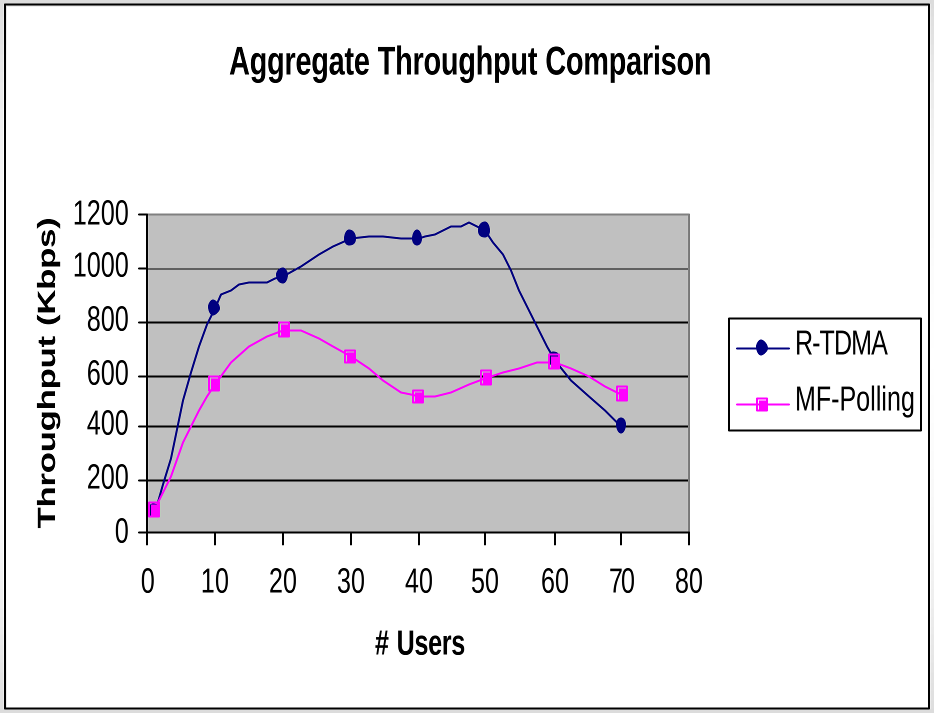
- Devised a metric which observes the product of number of users and throughput.

- The MF-Polling system supports a large user population compared to the R-TDMA system.



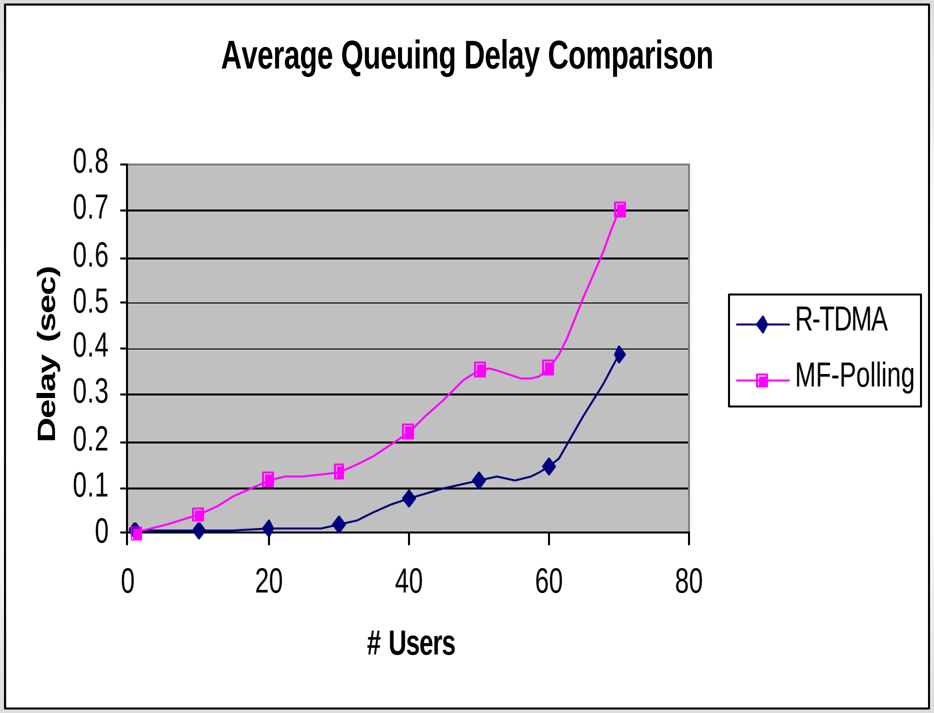
FTP Low Download

- Throughput degradation greater for R-TDMA on account of high collision.
- Light load conditions lead to lower throughput for MF-Polling.



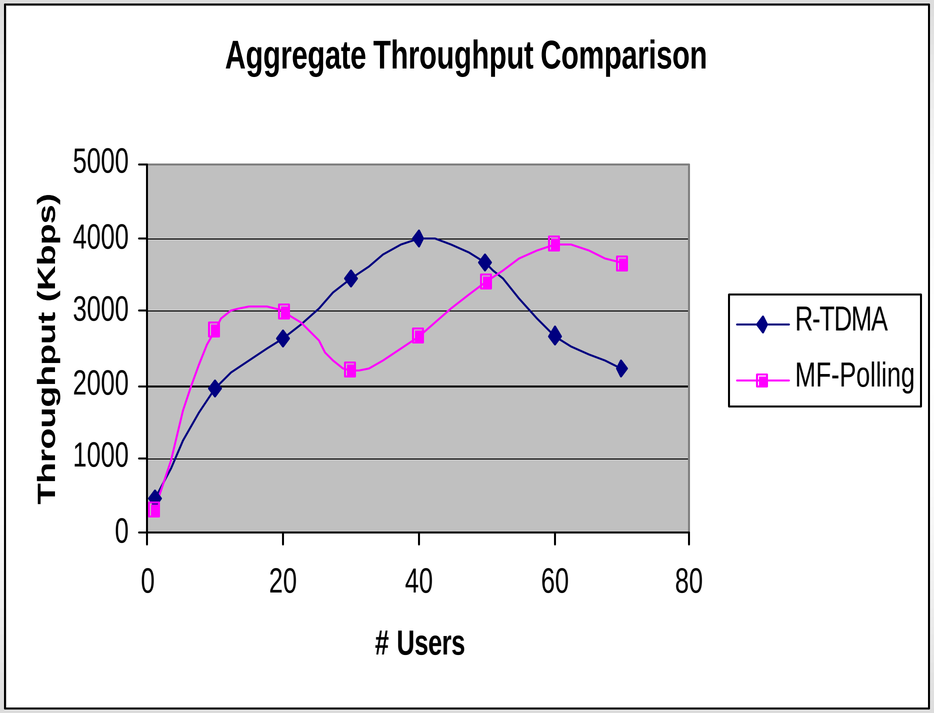
FTP Low Download (cont...)

- Greater collision rate leads to steep increase in queuing delay for R-TDMA for a large user population.
- Queuing delay for MF-Polling is higher than R-TDMA as data transmission is dependent on the polling cycle period.



FTP High Download

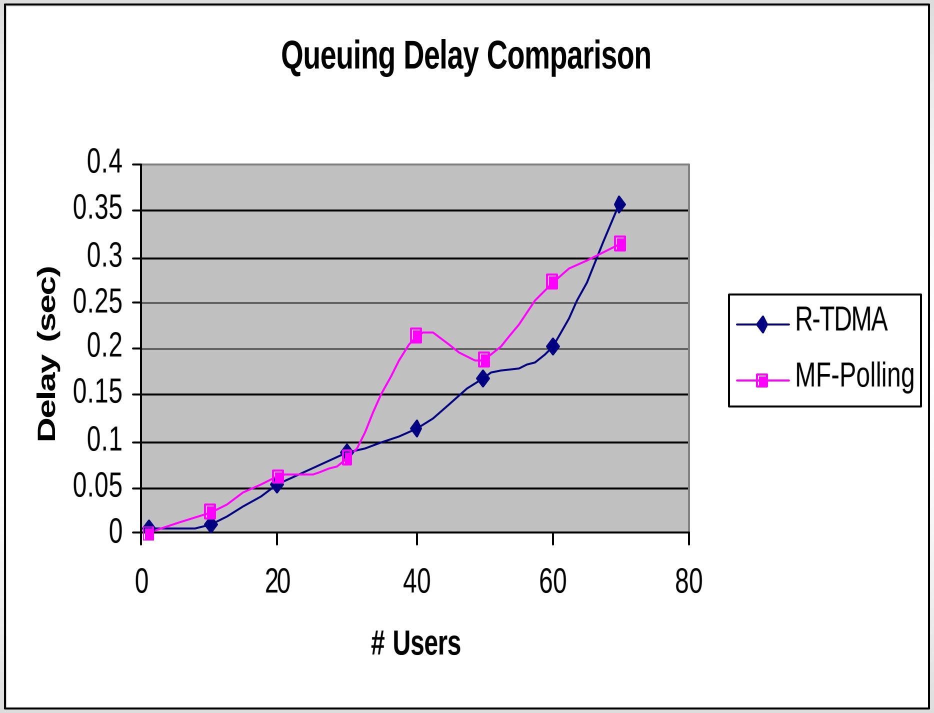
- Gradual rise in throughput for R-TDMA on account of reservation effect.
- Large timeout value leads to lower contention for MF-Polling for higher number of users and thus performs better.



FTP High Download (cont...)

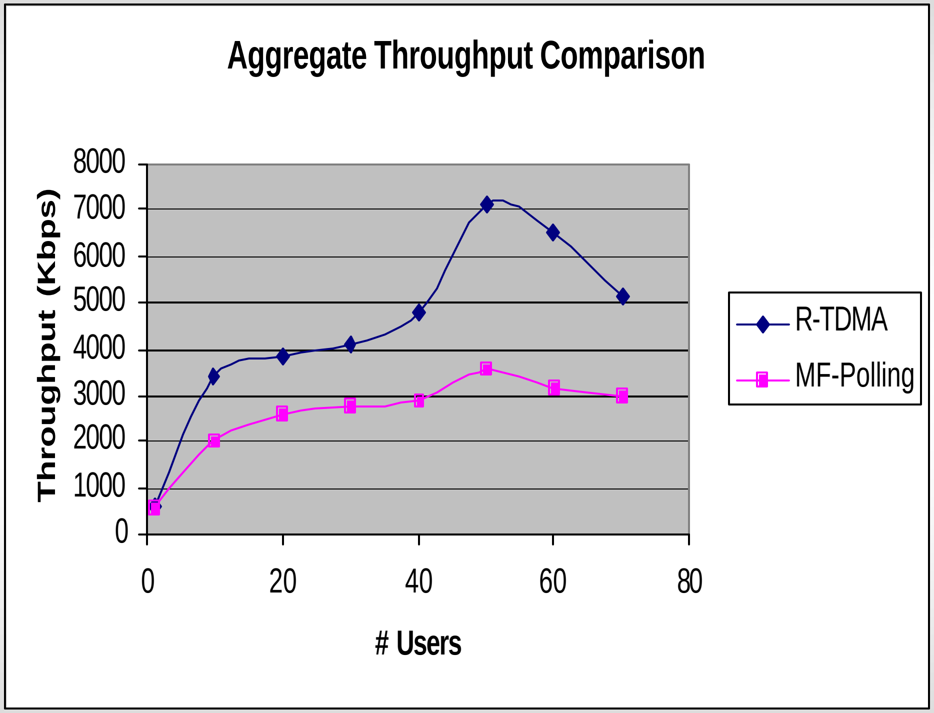
- Greater collision rate and variable number of slots leads to steep increase in queuing delay for R-TDMA for large number of users in the system.

- Queuing delay for MF-Polling improves on account of reduction in contention delay and performs better as compared to the previous test case.



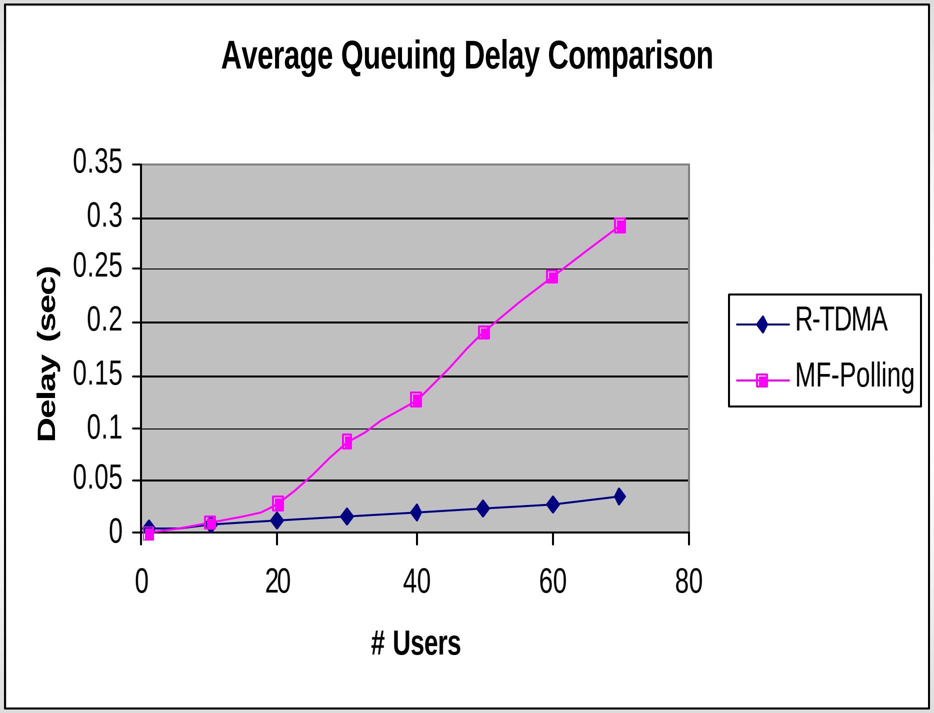
HTTP Light Browsing

- Larger amount of data, hence higher frame efficiency and continued reservation for the R-TDMA system.
- MF-Polling throughput limited by the associated polling cycle time.



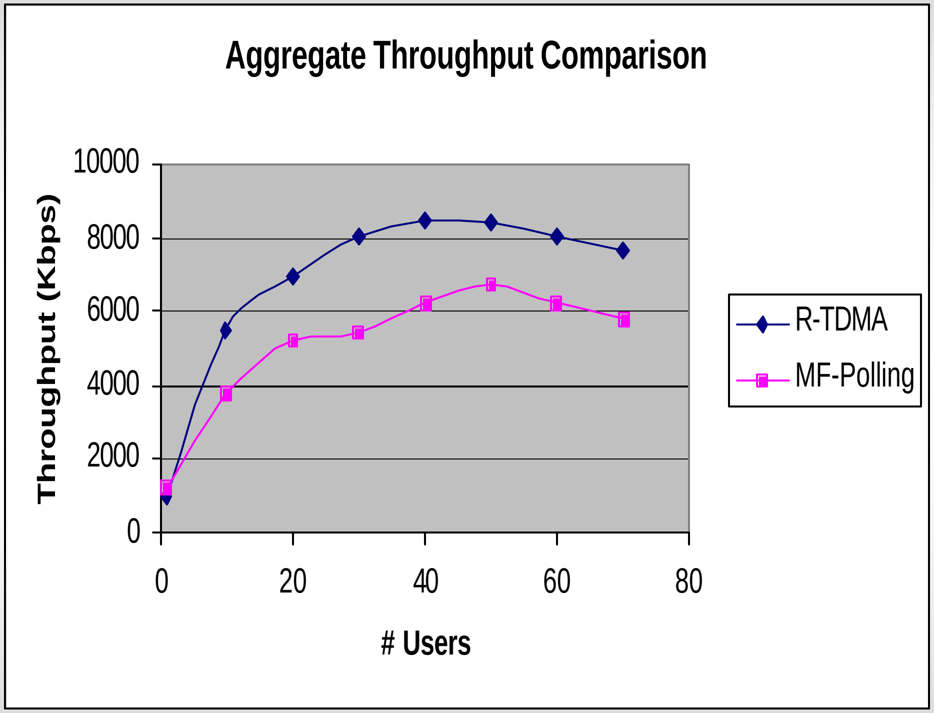
HTTP Light Browsing (cont...)

- Reservation effect leads to lower contention and lower queuing delay values for R-TDMA.
- MF-Polling performance hampered on account of the large values of polling cycle time.



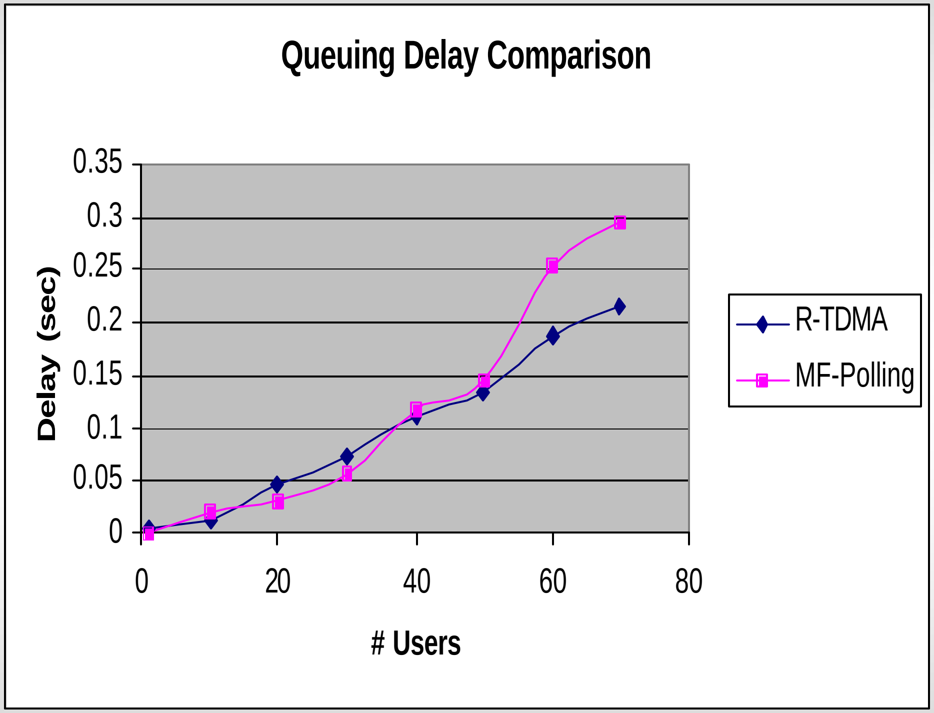
HTTP Heavy Browsing

- Larger amount of data, hence higher frame efficiency and continued reservation for the R-TDMA system.
- MF-Polling throughput limited by the associated polling cycle time.



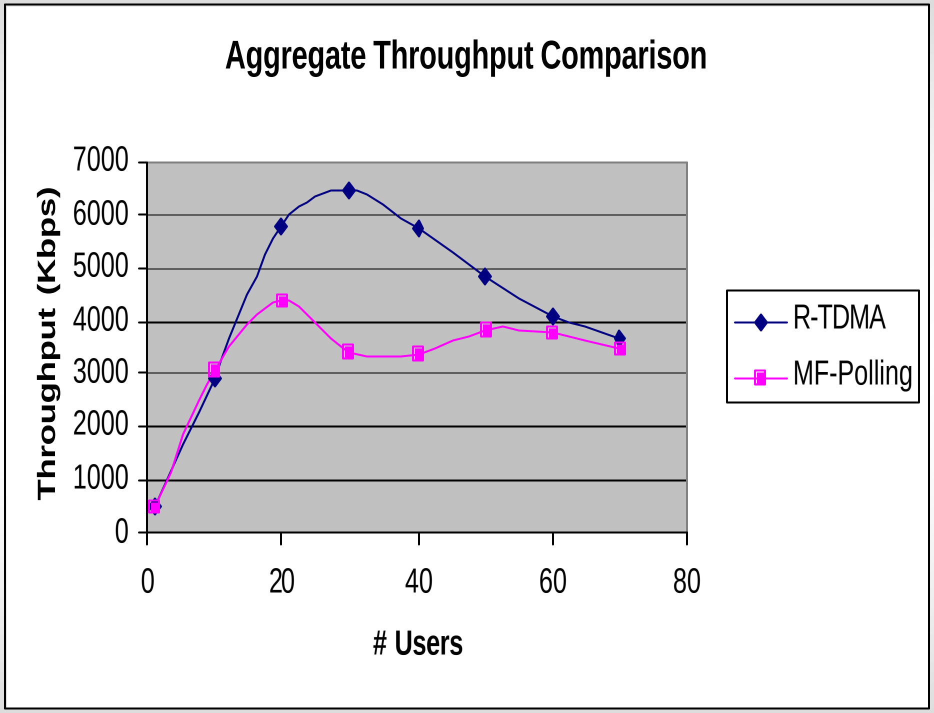
HTTP Heavy Browsing (cont...)

- Reservation effect in R-TDMA leads to lower contention. However, prolonged reservation leads to high queuing delay comparable to MF-Polling.



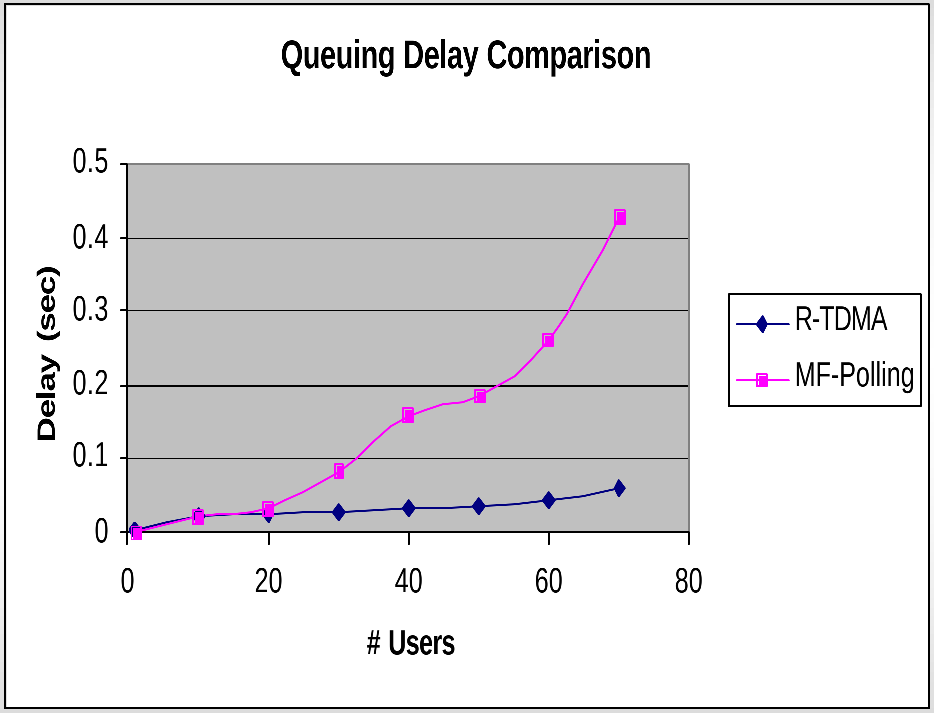
Medium Load

- Combination of FTP Low Download and HTTP Light Browsing.
- MF-Polling throughput performance stable over a large range of users and hence can support a large user population.



Medium Load (cont...)

- MF-Polling queuing delay suffers on account of large contention delay and polling cycle time.
- Continuous data on account of HTTP traffic aids R-TDMA to maintain reservation and thus has lower queuing delay values.



Proposed Design Improvement

Proposed Design Improvement - Parameter Selection

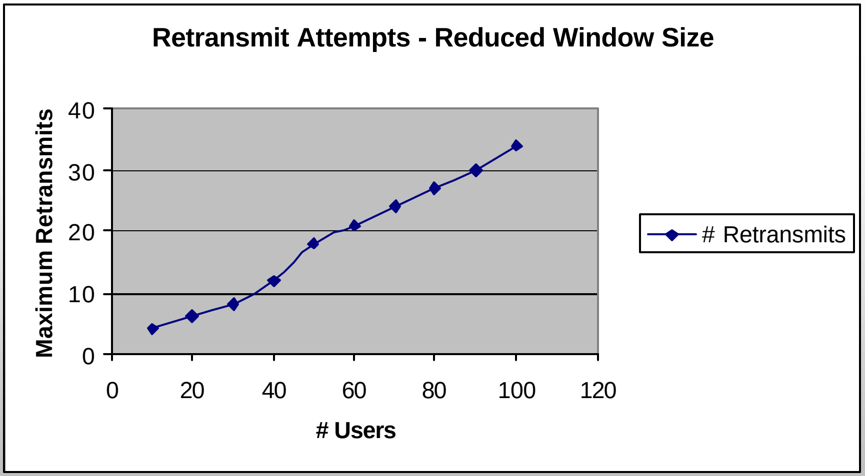
- Throughput directly affected by the queuing delay.
- Queuing Delay composed of
  - Contention Delay
  - Delay on account of system architecture.
- No architectural changes required for improving the performance of the contention mechanism.

Proposed Design Improvement - Reservation TDMA

- Varying number of slots cause mismatch between selection of frame for request transmission and number of contention slots available for that frame.
- Keep number of contention slots fixed to its maximum possible value.
- Reduces randomness as contention is dependent upon the frame that a user selects for request transmission.

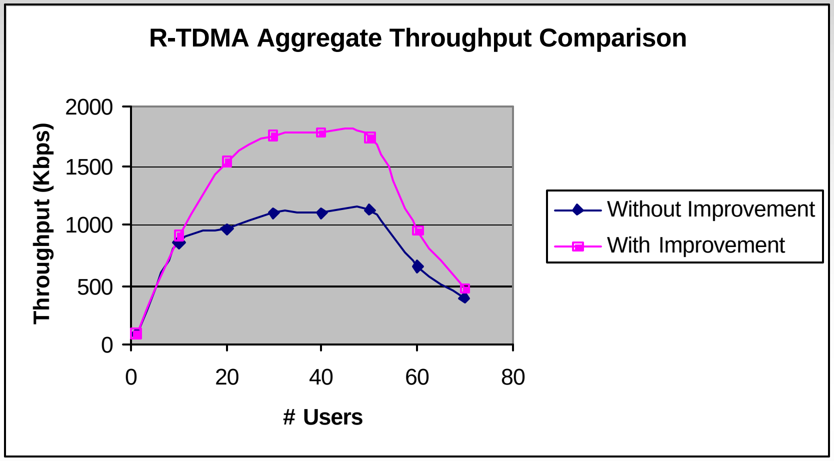
Proposed Design Improvement - Multi Frequency Polling

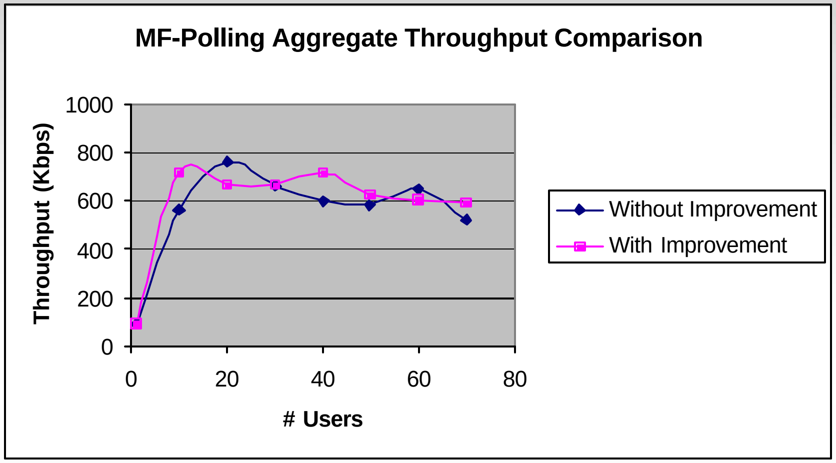
- Retransmission of request depends upon the available window size and polling cycle time.
- Contention delay can be controlled by reducing the maximum window size to a value such that, “The original maximum contention delay is not exceeded by the maximum number of retransmits for the reduced contention window”.
- Value for maximum contention window size reduced from 1024 to 32.

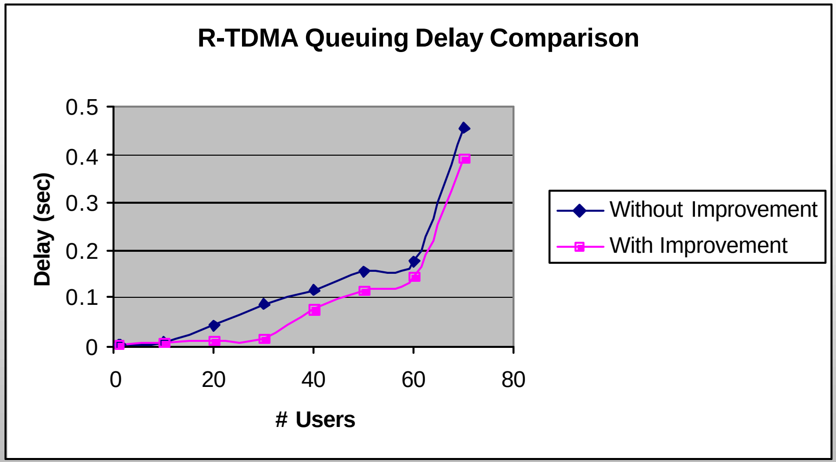


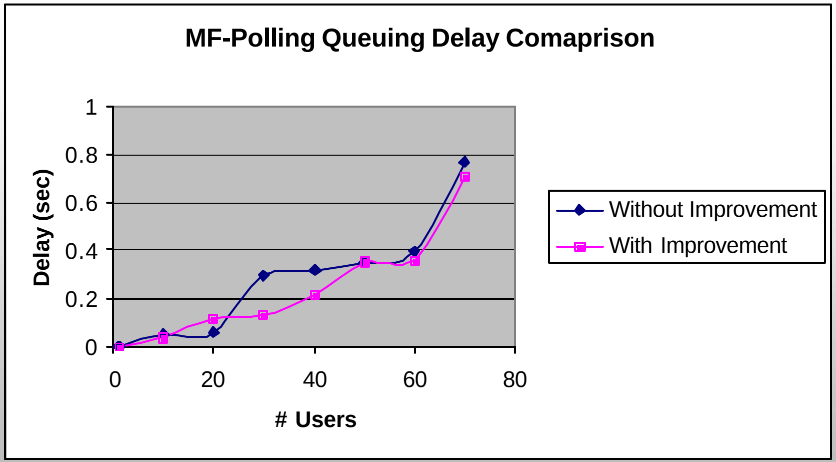
Performance Re-evaluation

FTP Low Download



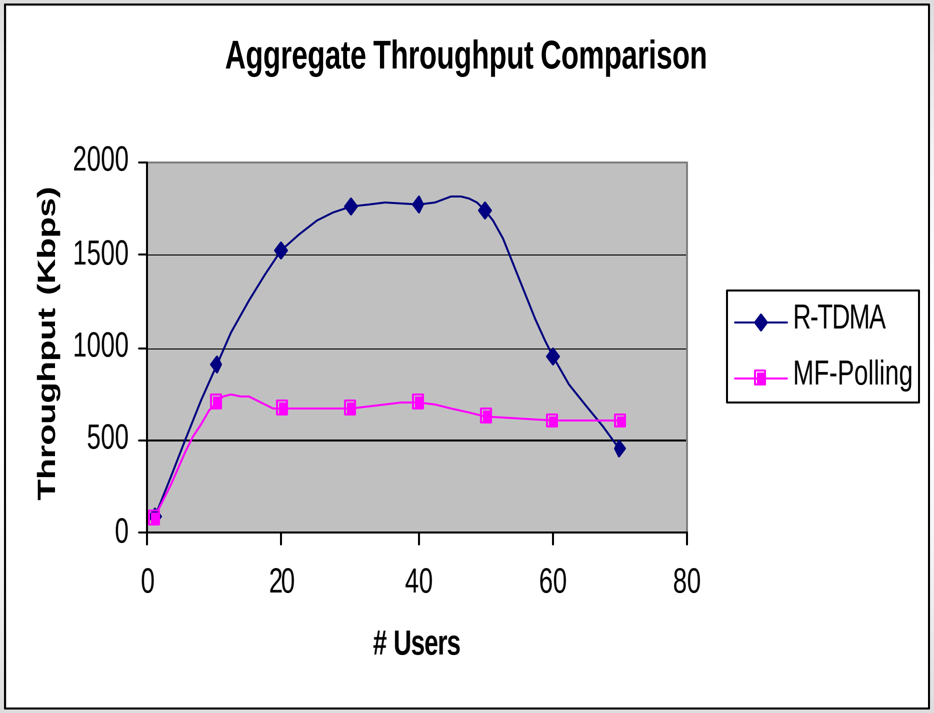






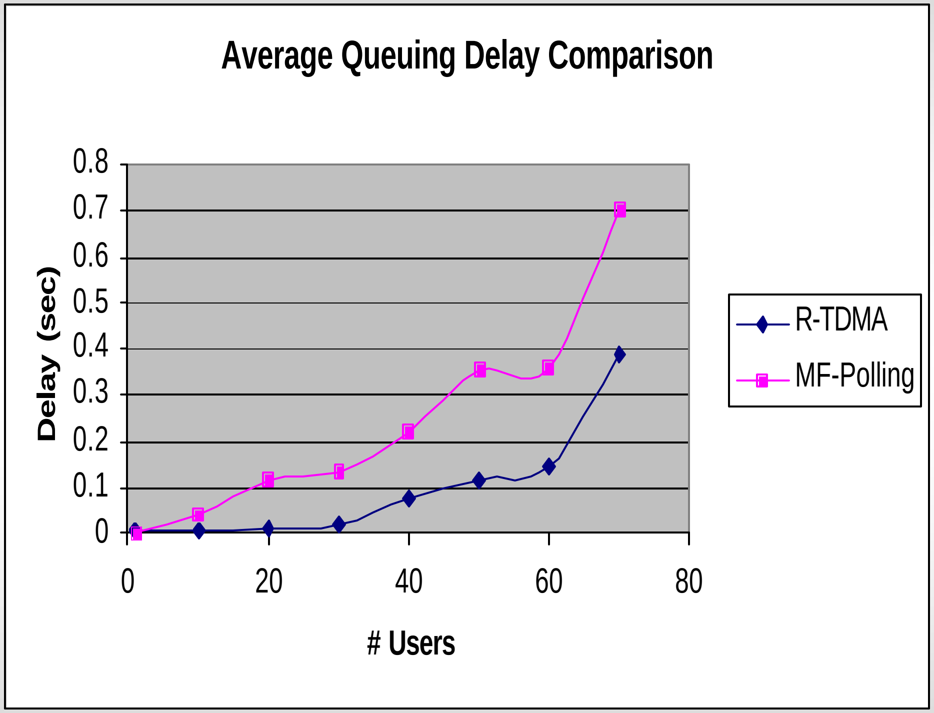
FTP Low Download (cont...)

- Throughput improved on account of reduction in queuing delay for both the protocols.

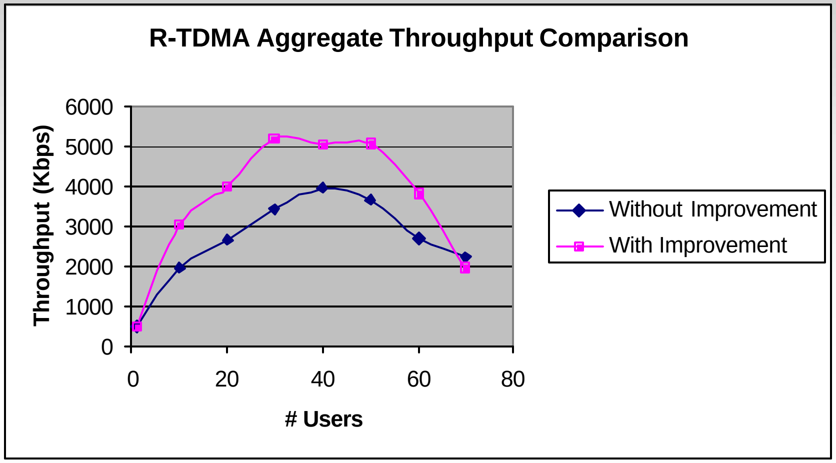


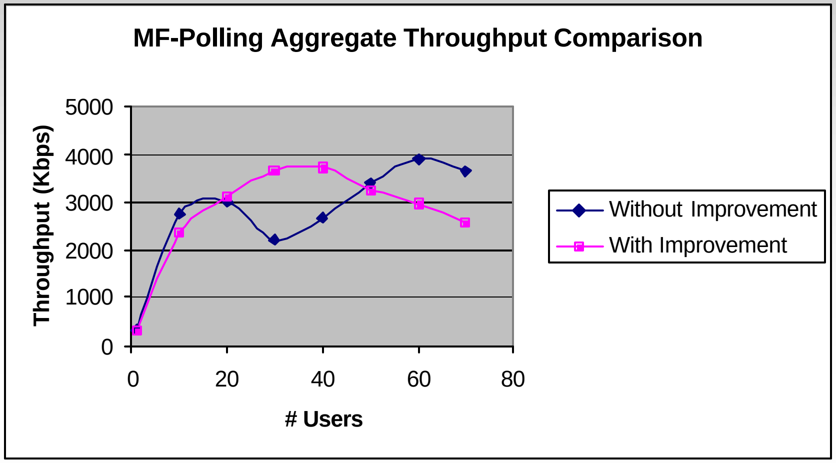
FTP Low Download (cont...)

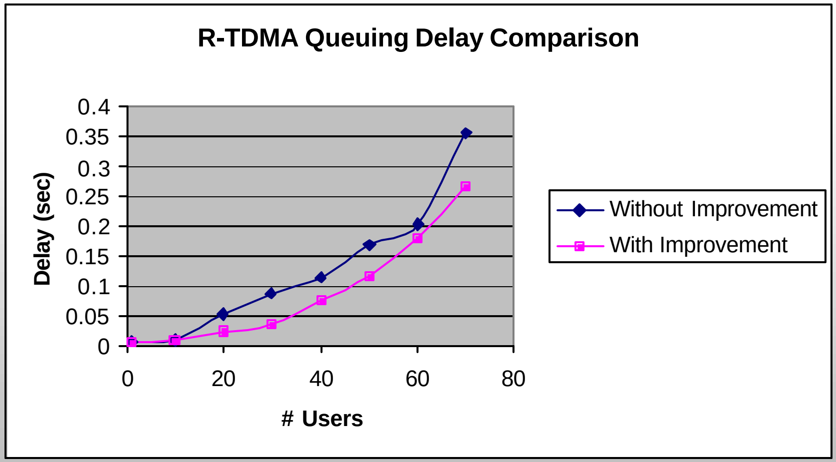
- Improved queuing delay performance for both the protocols. However, R-TDMA still performs better than MF-Polling.

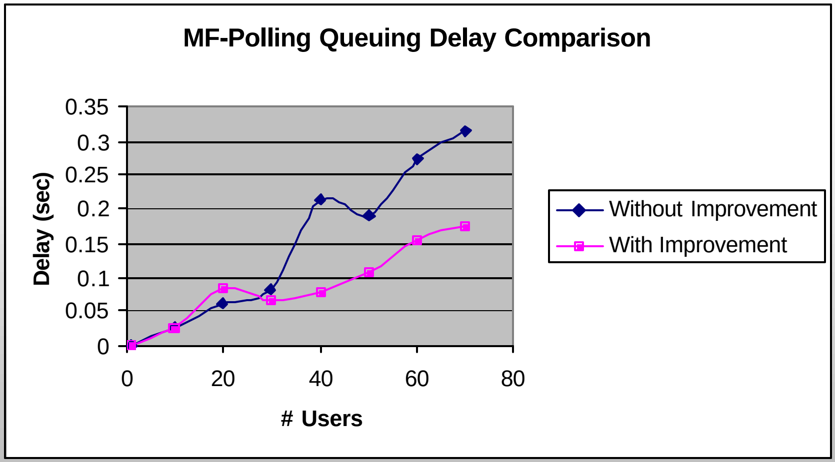


FTP High Download



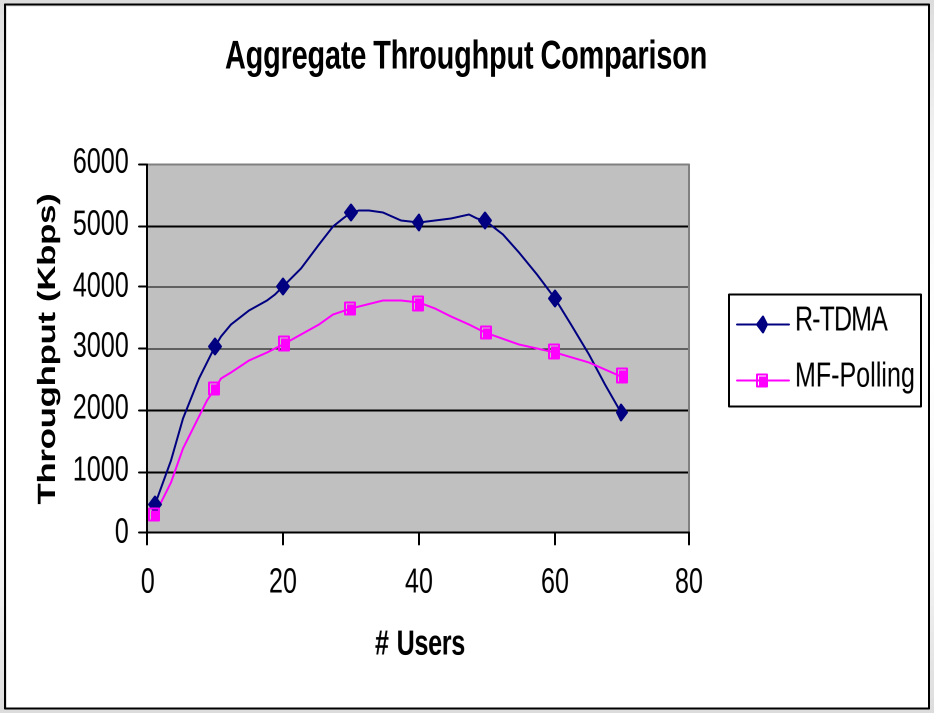






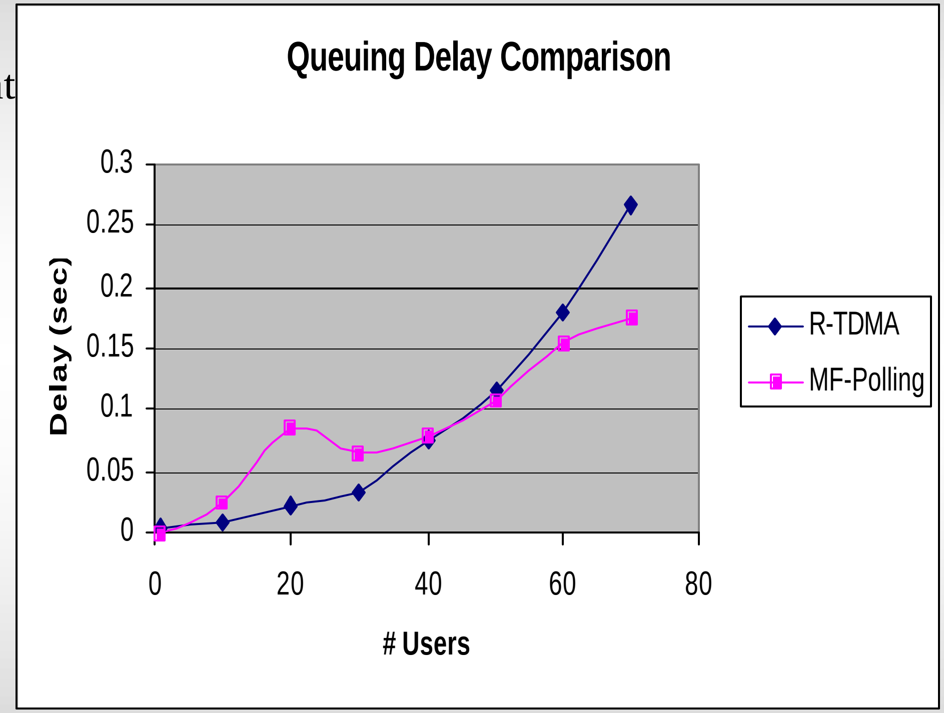
FTP High Download (cont...)

- Improved throughput and graceful degradation for MF-Polling on account of improved queuing delay performance.

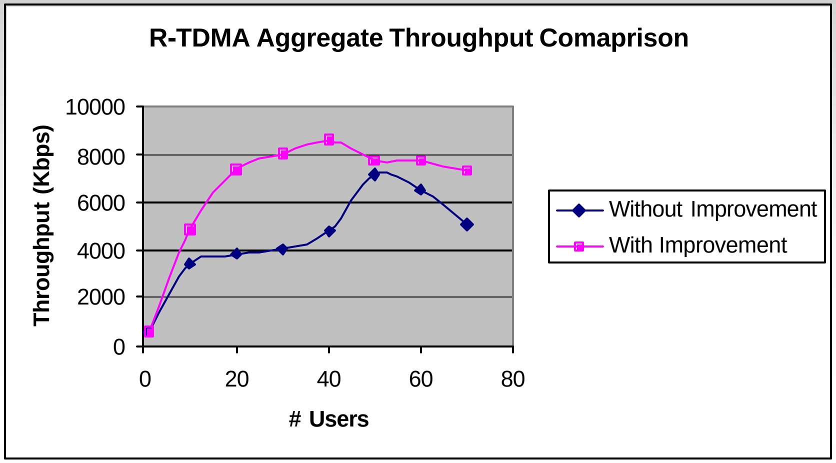


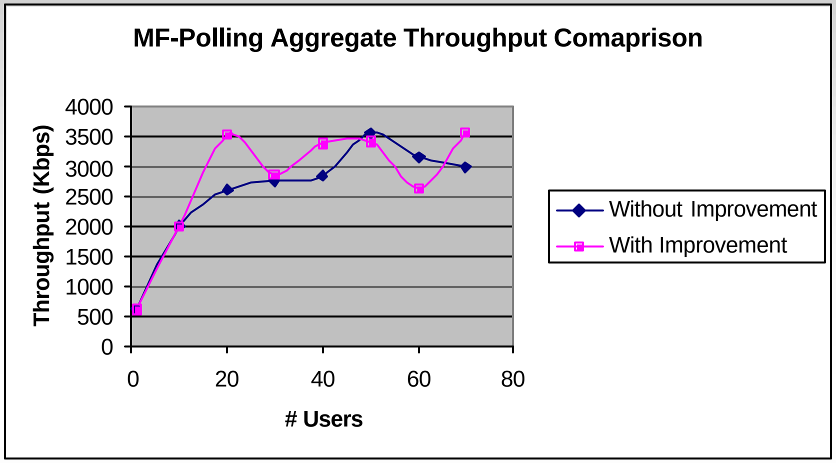
FTP High Download (cont...)

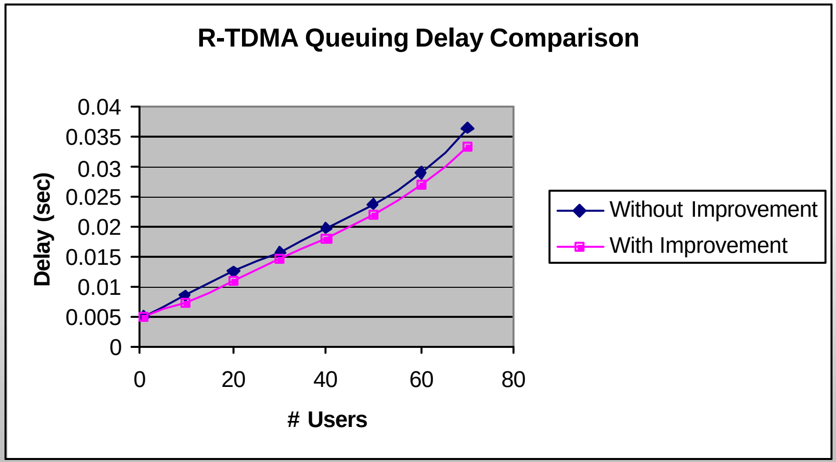
- Queuing delay performance for MF-Polling becomes comparable to that of R-TDMA and is better for more number of users in the system

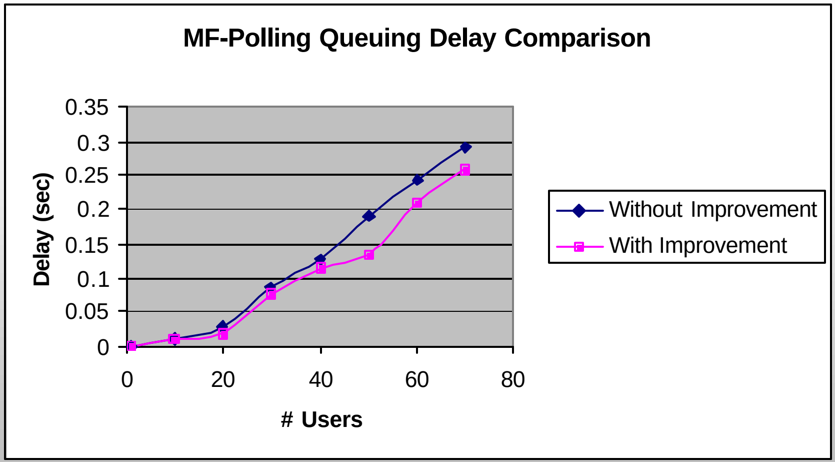


HTTP Light Browsing



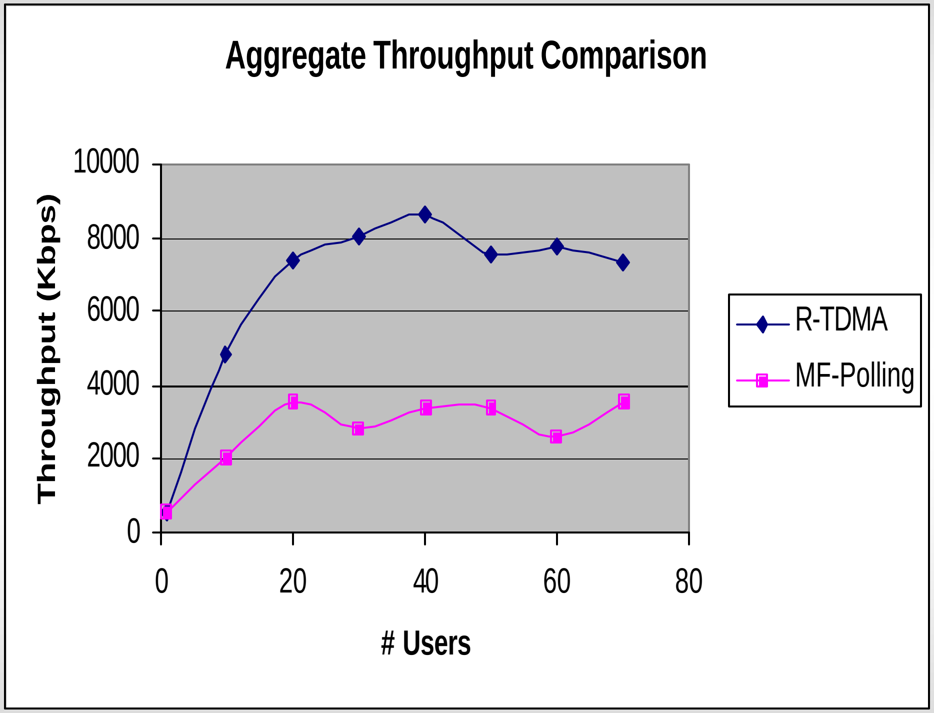






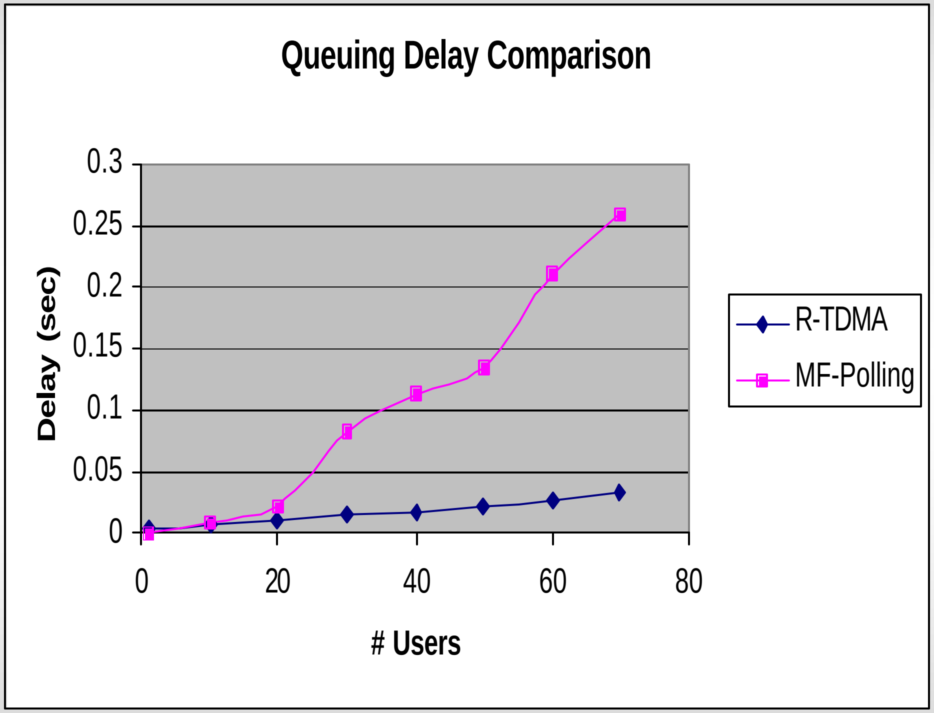
HTTP Light Browsing (cont...)

- R-TDMA still performs better than MF-Polling and also has a stable range of throughput.

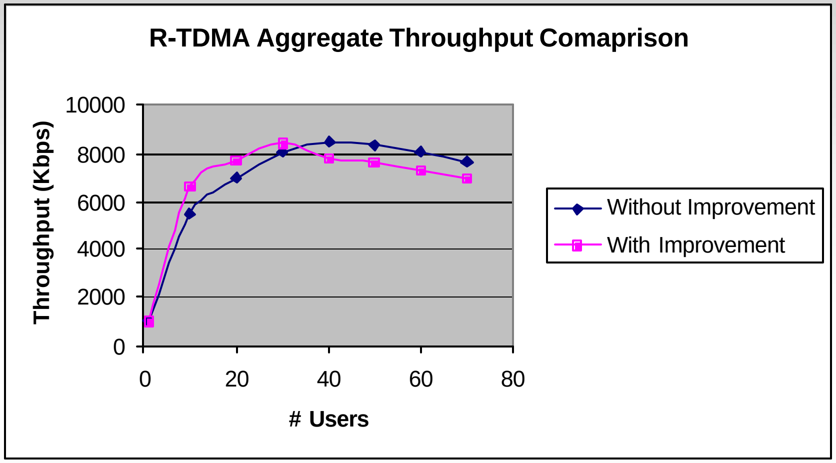


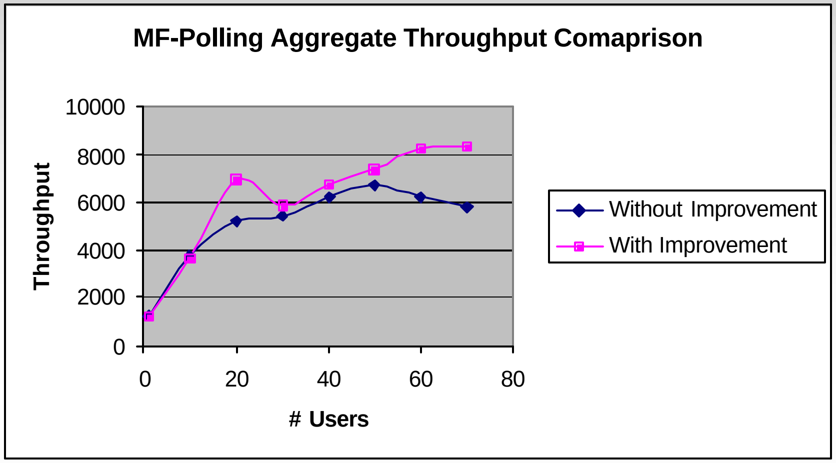
HTTP Light Browsing (cont...)

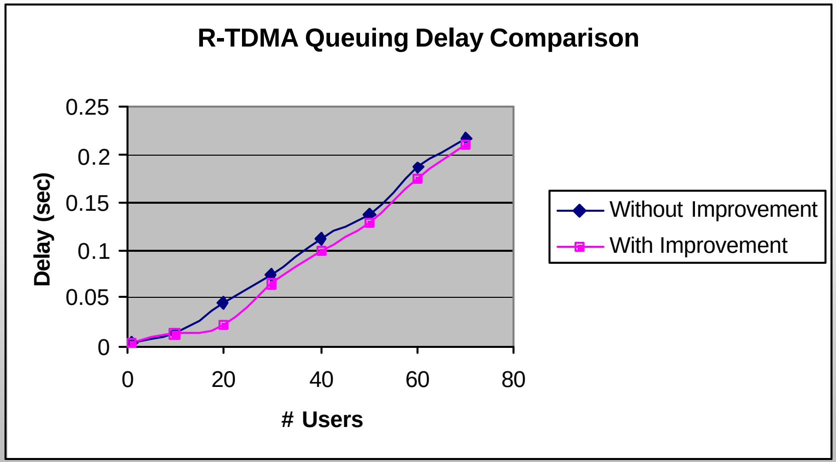
- Since there is less improvement in individual queuing delay performance, the overall comparison remains same as the case without improvement.

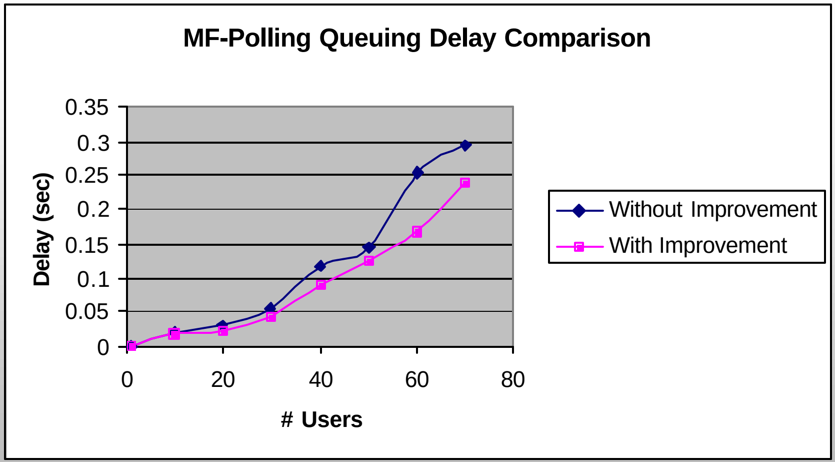


HTTP Heavy Browsing



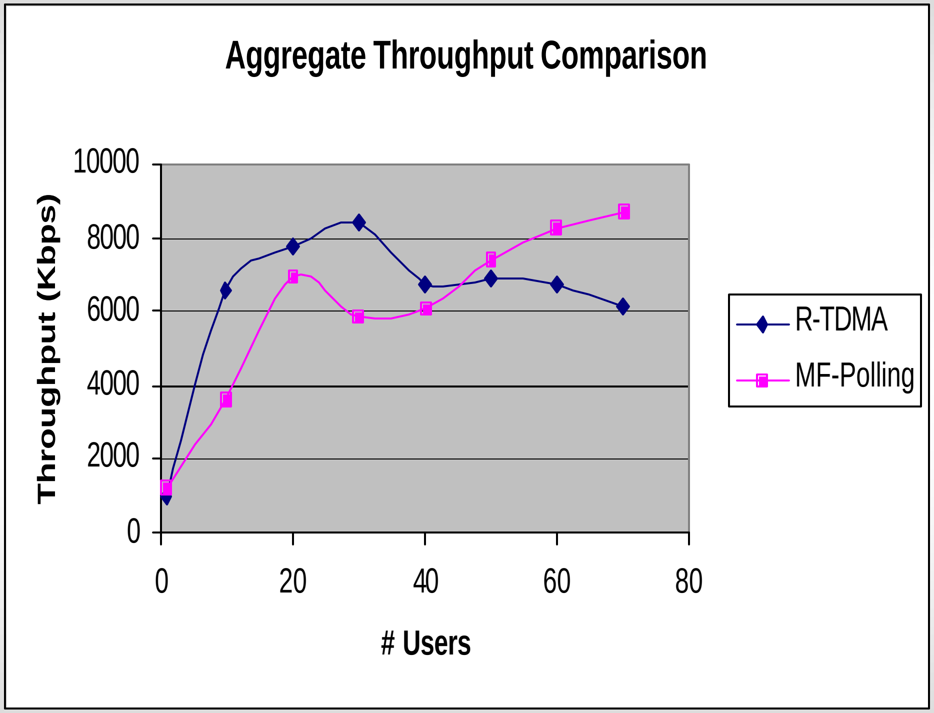






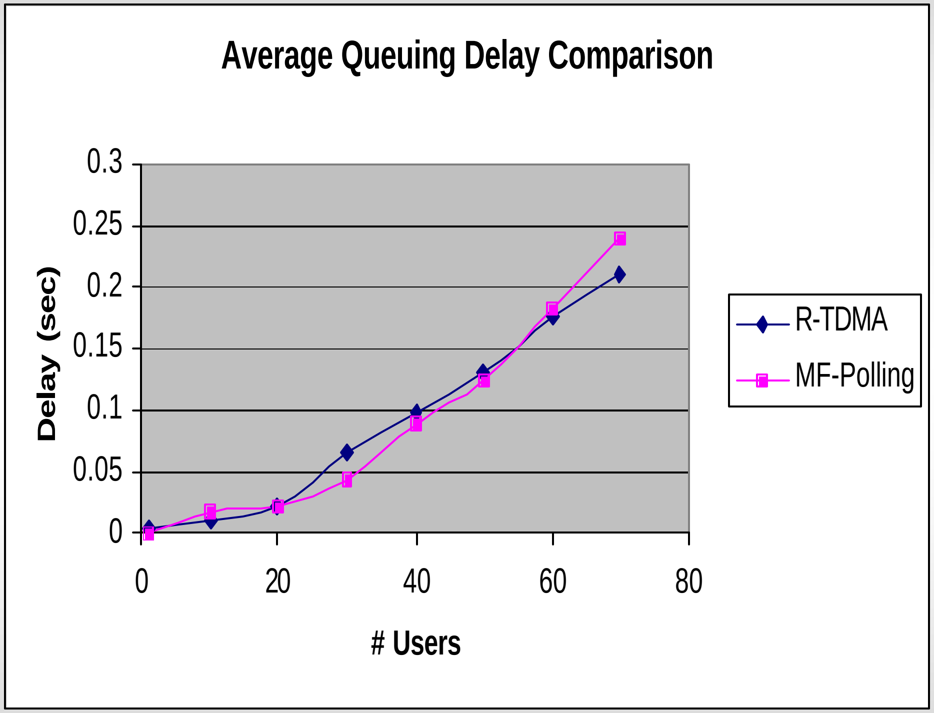
HTTP Heavy Browsing (cont...)

- Improved delay performance affects the throughput performance for MF-Polling.
- Reservation factor comes into effect for R-TDMA and hence reduced contention.

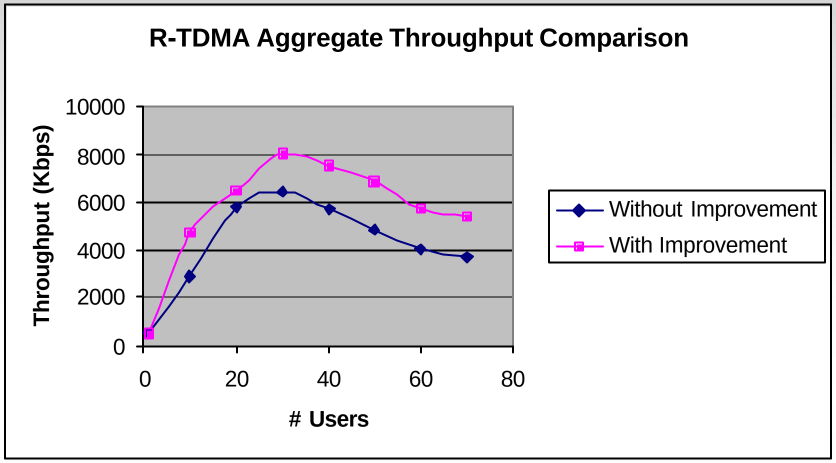


HTTP Heavy Browsing (cont...)

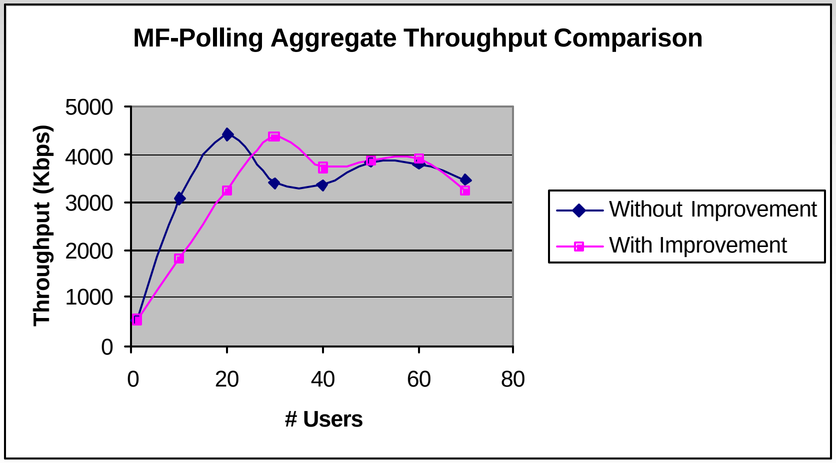
- MF-Polling queuing delay comparable to that of R-TDMA.



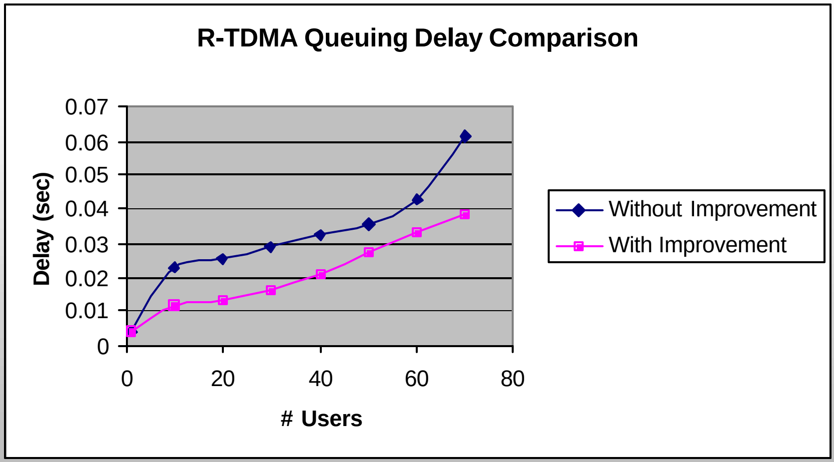
Medium Load



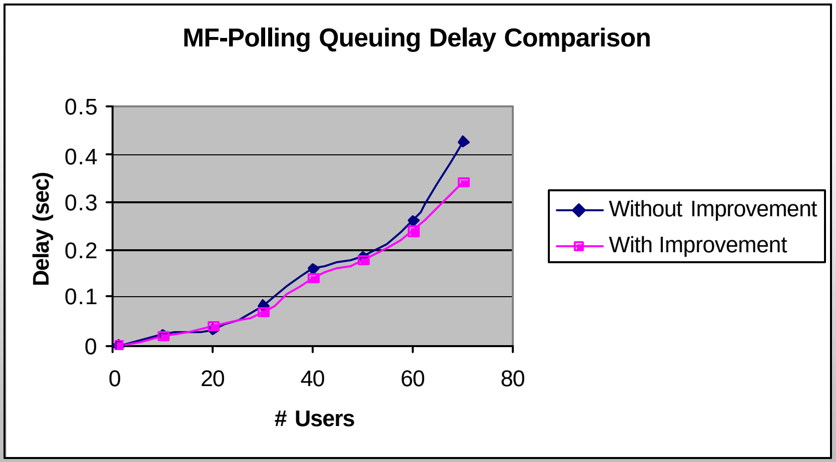
R-TDMA Aggregate Throughput Comparison
Throughput (Kbps)
10000
8000
6000
4000
2000
0
0
20
40
60
80
Users
Without Improvement
With Improvement



MF-Polling Aggregate Throughput Comparison
Throughput (Kbps)
5000
4000
3000
2000
1000
0
0
20
40
60
80
Users
Without Improvement
With Improvement



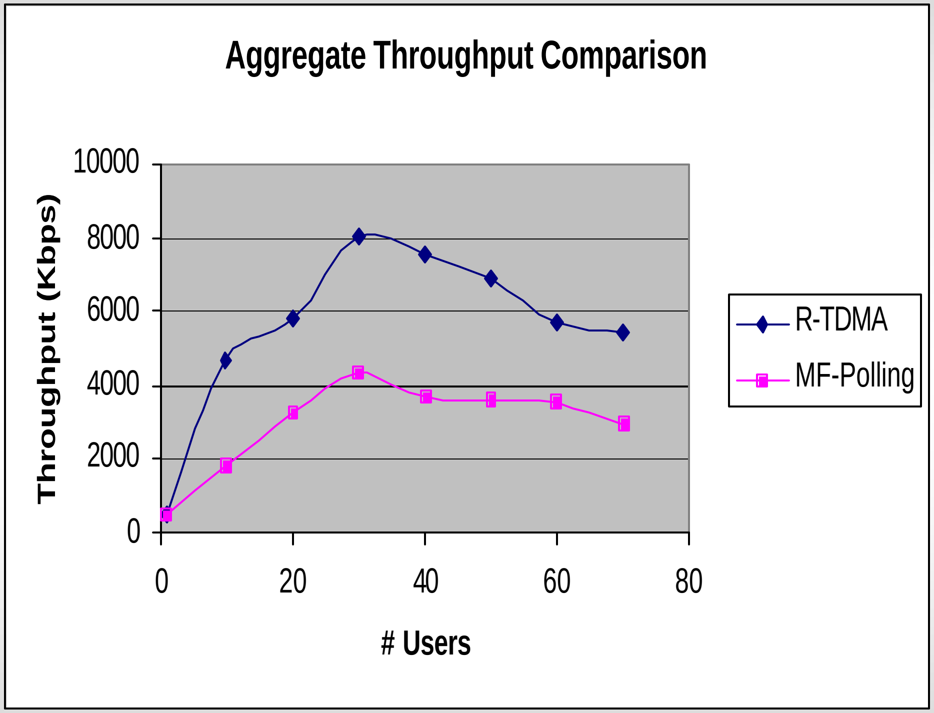
R-TDMA Queuing Delay Comparison
Delay (sec)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
Users
Without Improvement
With Improvement



MF-Polling Queuing Delay Comparison
Delay (sec)
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
Users
Without Improvement
With Improvement

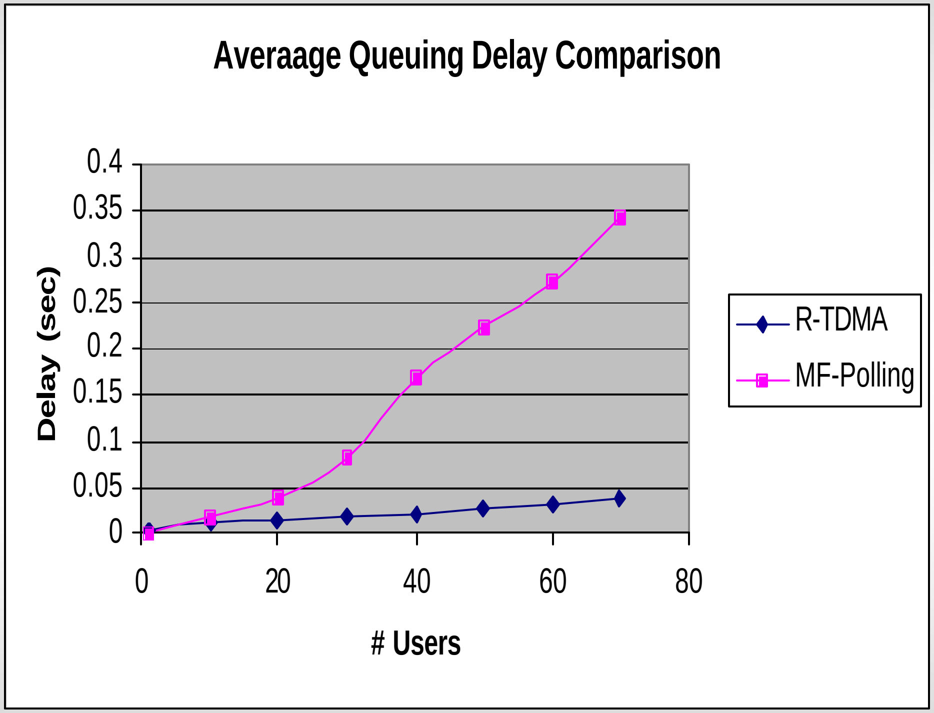
Medium Load (cont...)

- Improved queuing delay performance for the R-TDMA system improves its throughput and stabilizes it over a large range of users.



Medium Load (cont...)

- R-TDMA has lower values of queuing delay than MF-Polling due to reduced contention.



Conclusions and Future Work

Conclusions and Future Work

- Conclusions
  - Protocol architecture is critical in deciding the system performance. Thus, system design can be based upon the output parameter of concern.
  - Contention mechanism is as significant as the protocol architecture.
  - Design improvements recommended for applications that have stringent demands on delay values.
  - R-TDMA
    - R-TDMA provides better throughput and delay characteristics for traffic patterns that are continuous in nature.
    - The R-TDMA system is more suited to HTTP traffic than the MF-Polling system.

Conclusions and Future Work (cont…)

- MF-Polling
  - The MF-Polling system performs better under light load conditions or for traffic that is bursty in nature.
  - The MF-Polling system is more suited to FTP traffic than the R-TDMA system.
  - The MF-Polling system can support a larger user population, but delivers lower throughput and higher average queuing delay than the R-TDMA system.

Conclusions and Future Work (cont…)

- Future Work
  - Synthesize a MAC scheduler for the MF-TDMA system that would take advantage of the lower queuing delays, high throughput and larger supported user population.
  - Modify the contention mechanism that would take into account various types of users present in system. This allows us to develop a fully QoS-aware MAC system.

Questions ??