Feedback Consolidation in Point-to-Multipoint Connections of ABR Service in ATM Networks

Submitted by:
Tamer M. El-Sayed

Supervised by:
Prof. Dr. M. Nazeeh El-Dereni
Prof. Dr. M. Salah Selim
Dr. Magdy A. Ahmed

Overview

- **Traffic Management**
- **ATM Service Classes**
- **ABR Traffic Management Model**
- **Example Switch Algorithm: ERICA**
- **Point-to-Multipoint Connections**
- **Design Issues**
- **Related Work**
- **Proposed Algorithm**
- **Performance Evaluation**
- **Comparison between Algorithms**
- **Conclusions**
- **Future Work**

Traffic Management

- **Congestion** occurs when**:** Input Load>Output Capacity
- **Congestion Control:** reducing load during overload
- **Traffic Management:**
  Not only load reduction during overload
  Not only load increase during underload
  but ensures that users get their desired QoS in spite of varying load conditions
  ==> required even if the network is underloaded
- **Problem is difficult during periods of heavy load**
  ==> congestion control is the most important aspect of traffic management

ATM Service Classes

***CBR* (Constant bit rate):** Constant rate. Throughput, delay and dela variation guaranteed. Voice,video,circuit emulation(leased-line emulation

***VBR* (Variable bit rate):** Declare avg and peak rate.

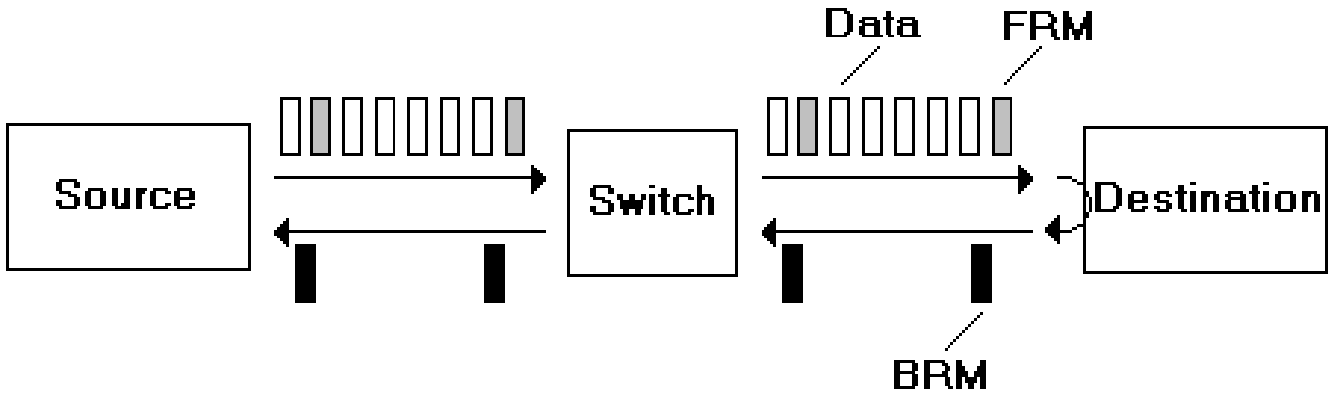
- **rt-VBR (Real-time):** Max delay and delay variation guaranteed. Voice and vid applications (interactive compressed video).
- **nrt-VBR (non-real time):** No delay Bounds guaranteed. Non Real-time applicatio with bursty traffic characteristics (airline reservation, banking transactions).

***ABR* (Available bit rate):** Min rate guaranteed. Follows feedbac Network gives max throughput with min loss. Designed for normal da traffic (file transfer, e-mail)

***GFR* (Guaranteed Frame Rate):** Network commits to carry cells complete frames at MCR. Traffic>MCR will be delivered if availab resources.No delay bounds. Support non-real-time applications

***UBR* (Unspecified bit rate):** User sends whenever it wants. N feedback. No guarantee. Cells may be dropped during congestion.

ABR Traffic Management Model

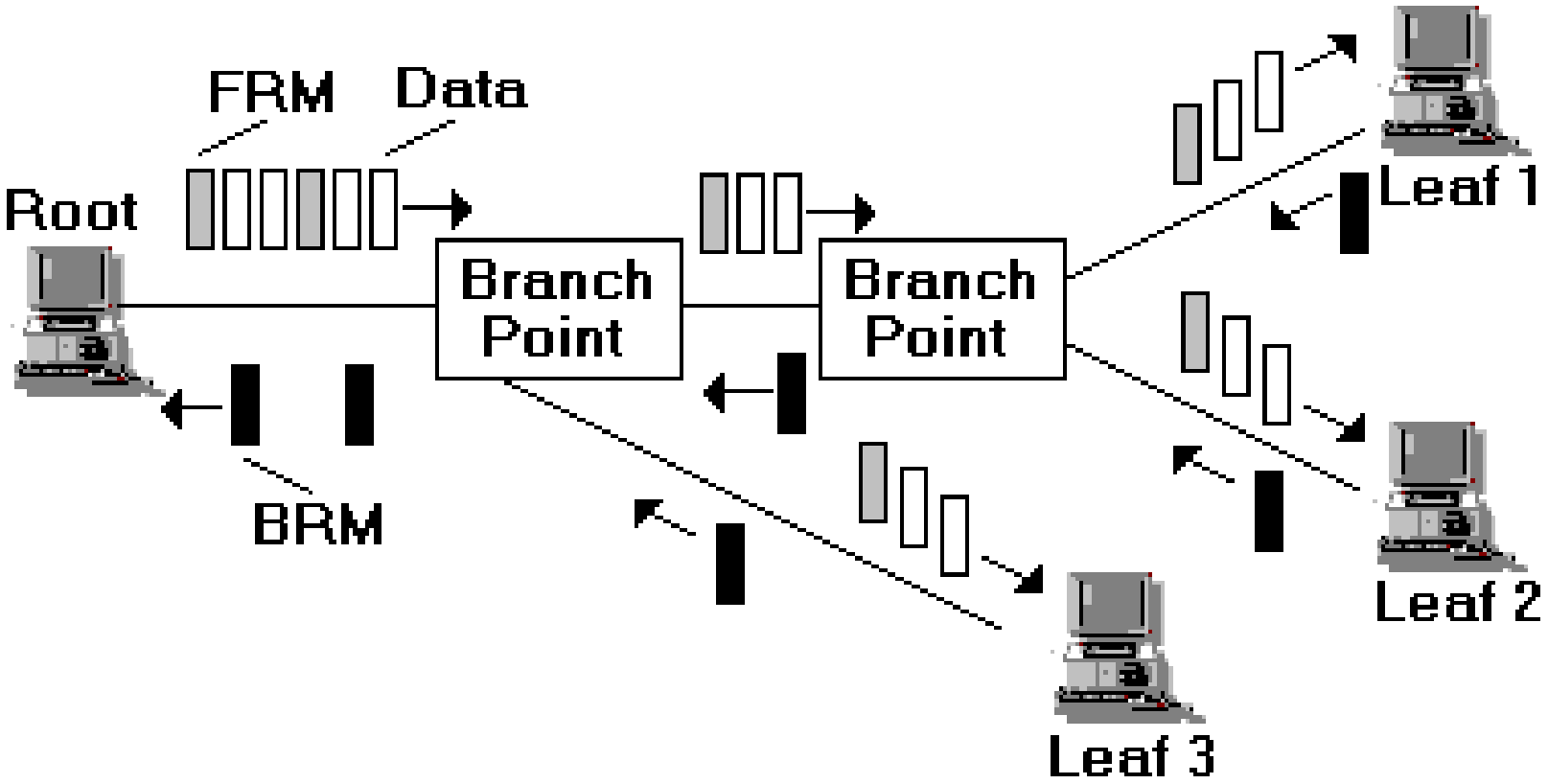


- Rate-based end-to-end closed loop model
- Every Nrm cells, the sources send a RM cell (FRM)
- The switches measure load over a period
- The destination returns the cell (BRM) to the source
- The switches specify explicit rate (ER) in cell
- The source adjusts the transmission rate (ACR)

Example Switch Algorithm: ERICA

- Explicit Rate Indication for Congestion Avoidance
- Set target rate, say, at 90% of link bandwidth
- Monitor input rate and number of active VCs *k*
- Overload = Input rate/Target rate
- This VC's Share = CCR/Overload
- Fairshare = Target rate/ *k*
- ER = Max(Fairshare, This VC's share)
- ER in Cell = Min(ER in Cell, ER)

Point to Multipoint Connections



Point to Multipoint Connections

- Applications: audio,video conferencing, distance learning, VoD, distributed games, replication,etc.
- Source should transmit at the minimum rate of all branches
- FeedBack Implosion: #BRM is proportional to #leaves
- Feedback Consolidation avoids it
- Consolidation Noise: BRM generated does not consolidate feedback from all branches

Design Issues

- Which component generates the BRM cell ?
  - Branch point or Destination
- What is the condition to trigger sending a BRM ?
  - Wait for all or …
- How can the ratio #BRM / #FRM be controlled ?
  - Constant or controlled
- How are non-responsive branches handled ?
  - Time out or counter

Related Work

[1] Roberts Algorithm (1994)
[2] Tzeng and Siu Algorithm (1995)
[3] Ren et al. Algorithm1 (1996)
[4] Ren et al. Algorithm2 (1996)
[5] Moh Algorithm (1997)
[6] Fahmy et al. Algorithm 3 (1998)
[7] Ammar et al. Algorithm (1998)
[8] Chen et al. Algorithm (1999)
[9] Ros et al. Algorithm (2000)

[1] *Roberts Algorithm (1994)*

- BRM cells are returned when FRM cells are received,and contain the minimum of the values indicated by the received BRM cells after the last sent BRM cell.
- FRM cells are duplicated and multicast to all branches at the branch point.
- **Advantages**: fast transient response
- **Disadvantages**: high implementation complexity, consolidation noise

[2] *Tzeng & Siu Algorithm (1995)*

- Ensuring that at least one BRM cell has been received from a branch before turning around an FRM.
- **Advantages**: less consolidation noise
- **Disadvantages**: high implementation complexity, slower transient response

[3] *Ren et al. Algorithm 1 (1996)*

- The BRM that is received from a branch immediately after an FRM has been received by the branch point is passed back to the source, carrying the minimum value.
- **Advantages**: low implementation complexity
- **Disadvantages**: slower transient response, high consolidation noise

[4] *Ren et al. Algorithm 2 (1996)*

- A BRM is passed to the source only when BRM cells have been received from all branches.
- **Advantages**: low consolidation noise
- **Disadvantages**: slow transient response

[5] *Moh et al. Algorithm (1997)*

- **BRM cells are returned when FRM cells are received and one of the following conditions is satisfied:**

  1. At least a new BRM cell is received with a requested rate less than or equal to the current rate.

  2. At least a new BRM cell is received, and the received FRM triggers the switch to compute an explicit rate less than or equal to the current rate.

  3. BRM cells have been received from all branches .

  4. At least a new BRM cell has been received by the switch, and Delta time-units have elapsed since the last sent BRM cell.

- **Advantages**: handling non-responsiveness, considering local congestion.
- **Disadvantages**: turning-around overhead, ignore non-responsive branches => consolidation noise, No RM ratio control.

[6] *Fahmy et al. Algorithm (1998)*

The **severe overload** should be immediately indicated to the source.

Overload is detected when the feedback to be indicated is much less than the last feedback returned by the branch point

Overload Condition: MER<Threshold*LER

SkipIncrease is incremented whenever a BRM cell is sent before feedback from all the branches has been received.

When feedback from all leaves indicates underload, and the value of the SkipIncrease is more than zero, this particular feedback can be ignored and SkipIncrease is decremented.

The **immediate rate calculation** option invokes switch congestion control algorithm whenever a BRM is received, and not just when a BRM is being sent. Hence overload at the branch point can be detected.

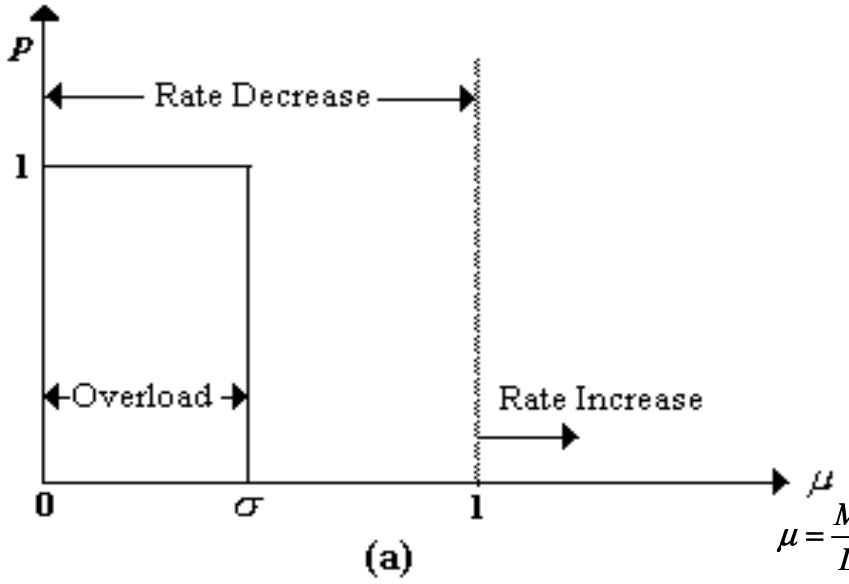
Advantages: RM ratio control, fast overload indication, local congestion indication

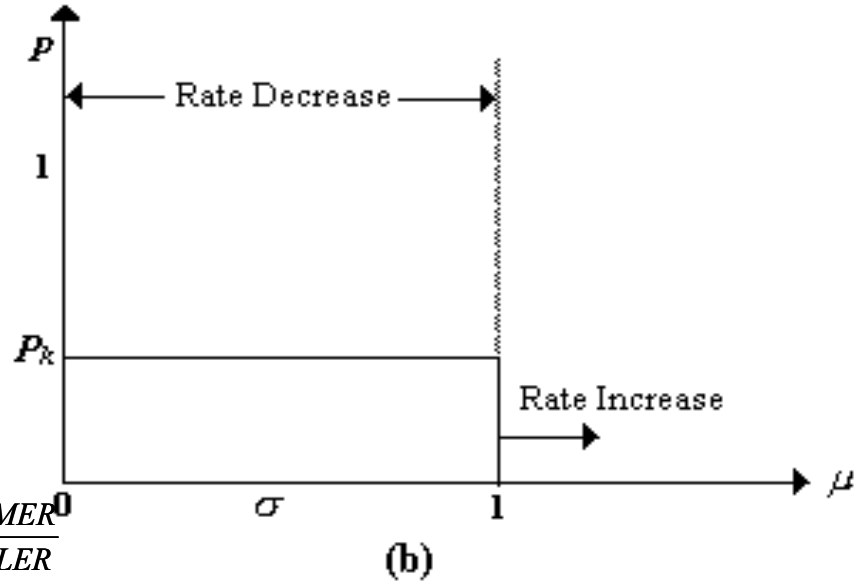
Disadvantages: no non-responsiveness handling, high complexity, threshold-dependent

[7] *Ammar et al. Algorithm (1998)*

- For each FRM cell extra BRM cells ***may be*** sent upstream during the consolidation procedure (i.e., before feedback from all downstream paths is received) so that any detected change in conditions can be passed back to the source more quickly.
- **Memory Enhancement:** The switches remember the previous explicit rates reported on their downstream branches. Until a new explicit rate is reported, the old value is used by the consolidation procedure.
- **Advantages:** probabilistic aggregation with less overhead, Memory enhancement
- **Disadvantages:** no non-responsiveness handling, feedback implosion, no local congestion indication

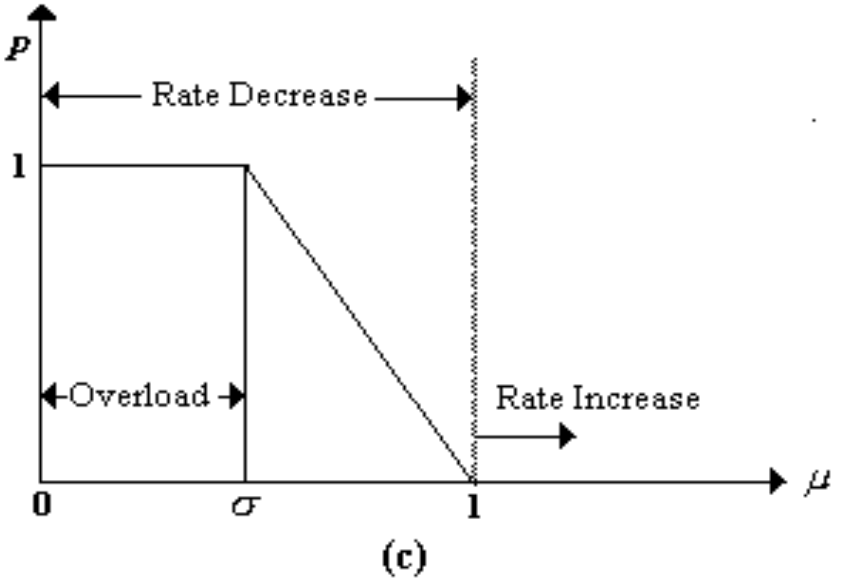
[8] *Chen et al. Algorithm (1999)*





$$\mu = \frac{MER}{LER}$$

$\mu = \text{MER/LER}$



[8] *Chen et al. Algorithm (Cont.)*

- **Advantages:** Chance for sending overload feedback even if low threshold, smooth rate decrease.
- **Disadvantages:** No local congestion check, No RM ratio control.

[9] *Ros et al. Algorithm (2000)*

- Keeps track of M smallest rates in BBM Matrix.
- There are two ways for which a branching switch may send a BRM cell back to the root:

  (1) Whenever a new bottleneck appears.

  (2) Whenever the number of feedback values received since the last time a BRM cell was sent is equal to the number of branches
- **Advantages:** low consolidation noise, very fast transient response.
- **Disadvantages:** Expensive (space: 2M values+time:maintain BBM matrix)

Proposed Algorithm

- **Check local congestion conditions** once when receiving first BRM cell after a new FRM cell => Decrease overhead by a factor of N.

  Why every FRM cell ?

  - Every new FRM => new CCR => new calculated rate.
  - In steady state, loads (then calculated rates) are stabilized.

- **Three ways to send BRM cell:**

  1- BRM cells are received from all branches

  2- **Severe** Overload: MER< Threshold * LER

  3- **Moderate** Overload:

  Threshold * LER < MER < LER with probability P

- All BRM cells sent by the switch before waiting for all branches to respond (2 and 3 above) are counted as extra BRM cells, then **RM ratio control** is necessary.

New RM Ratio Control Method

- RM ratio at the source should be one.
- In Fahmy et al. method: The branch point will not send underload information if ExtraBRM > 0 even if FRM-BRM>0 (RM ratio < 1)
- FRM-BRM is the new controller => faster convergence of RM ratio to one.
- Underload information has more chance to be sent.
- Straightforward to implement:

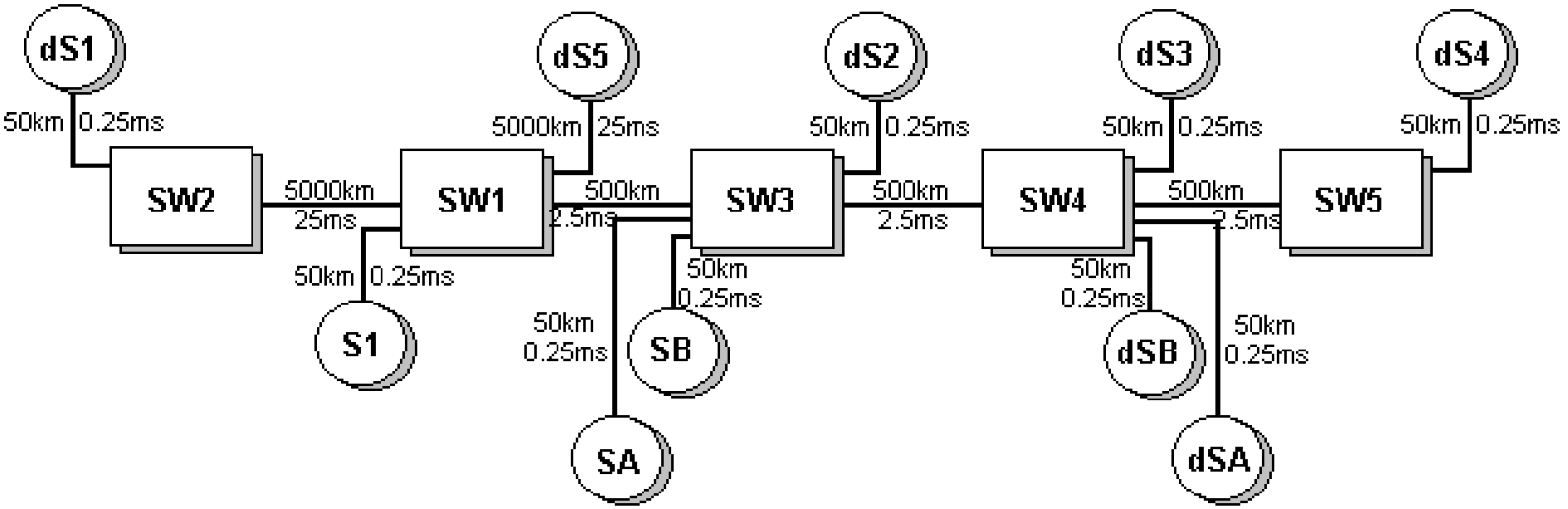
  FRM-BRM < = 0 instead of ExtraBRM > 0

- Could be used in any consolidation algorithm that permit sending extra overload BRM cell.

Performance Evaluation

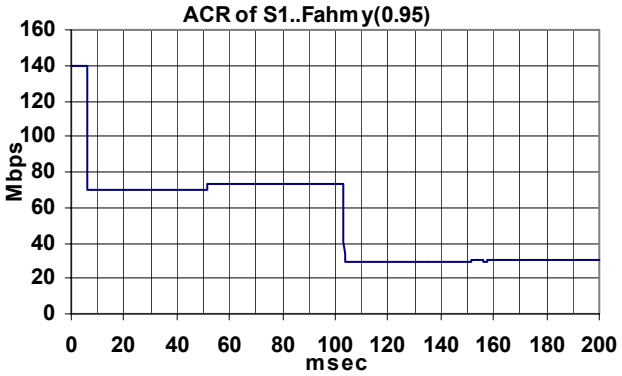
- All links have a bandwidth of 155.52 Mbps.
- The switch target utilization parameter is set at 90%.
- M in Ros = min (2, N).
- Testing 6 Algorithms (Fahmy, Chen, Ros, Proposed) + (Modified-Ros, Modified-Proposed).
- Low (0.05) and high (0.95) thresholds.
- Graphs: ACR, Bottleneck queue length, and Source RM ratio.

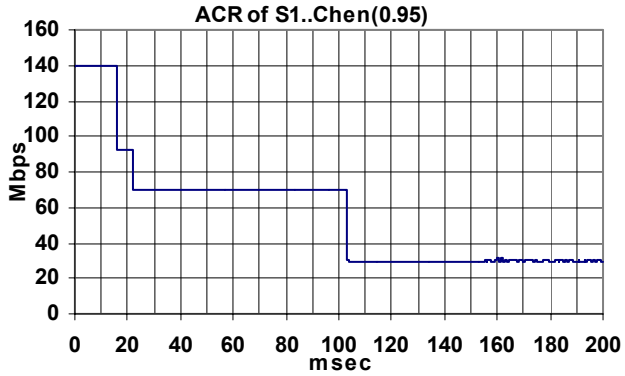
[1] *Parking Lot Configuration*

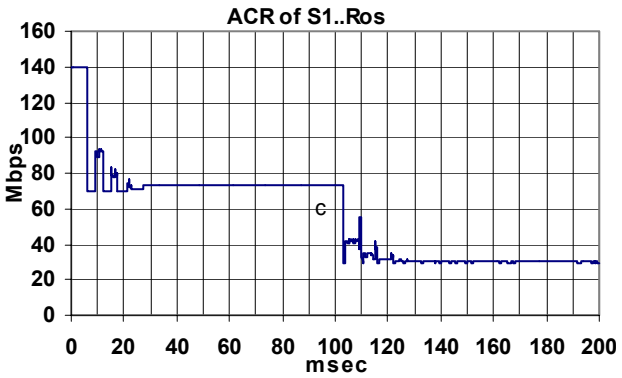


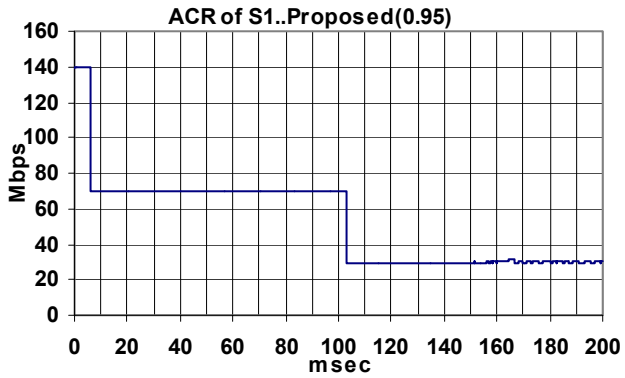
- One ABR P-to-MP : from S1 to dS1,dS2,…..,dS5
- One ABR P-to-P : from SA to dSA
- One CBR P-to-P : from SB to dSB [90 Mbps] active from100 ms
- The receiver dS5 is active from 100 ms.
- The link SW3-SW4 is the bottleneck link

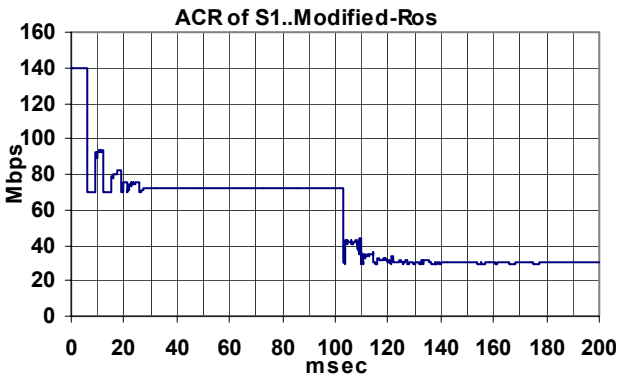
P.L. Config. : ACR(0.95)

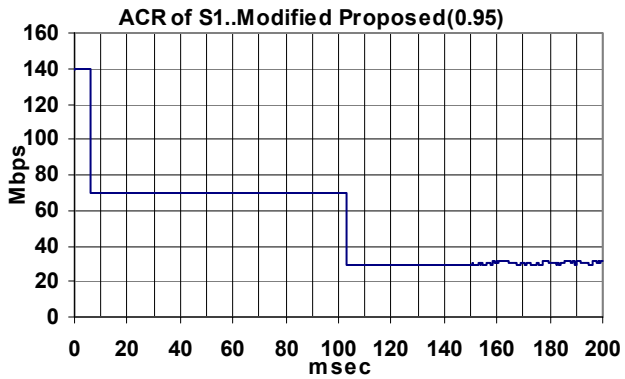




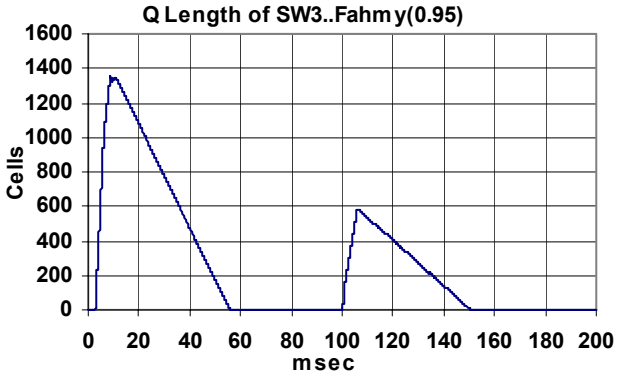


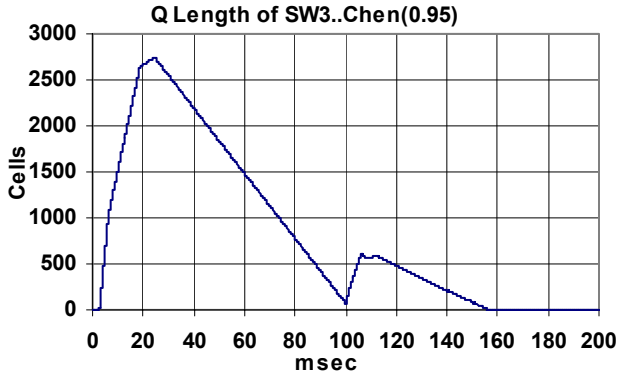


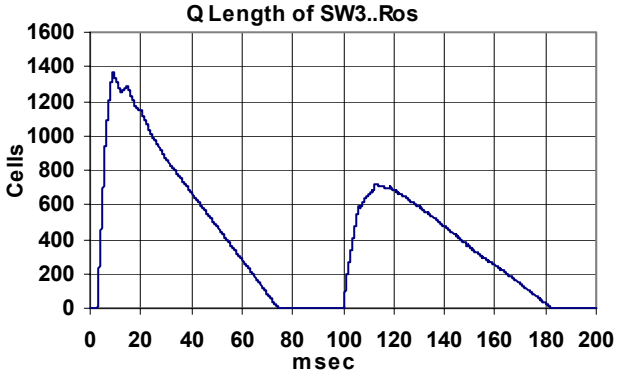


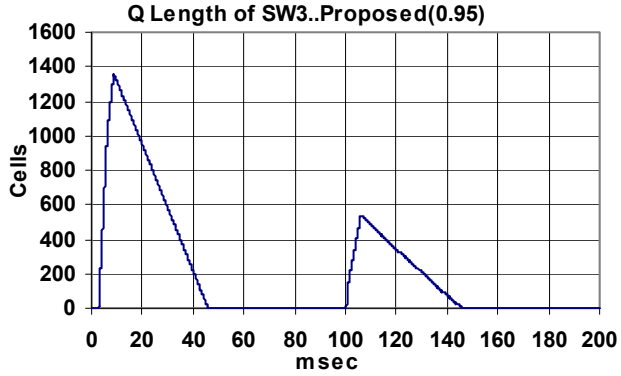


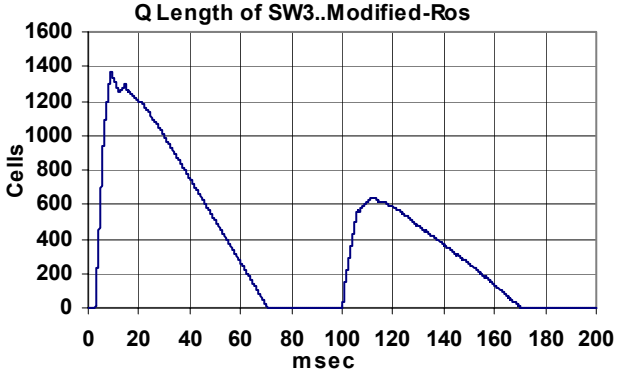
P.L. Config. : Queue Length(0.95)

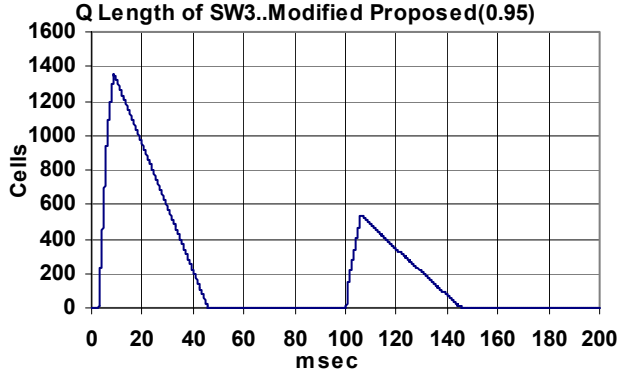




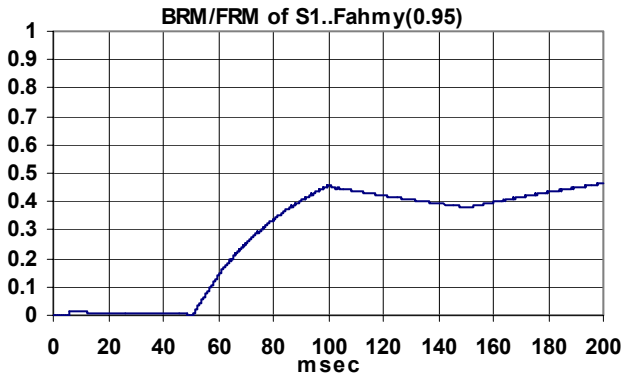


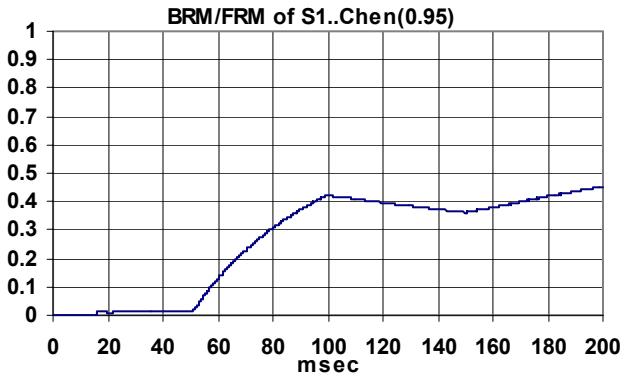


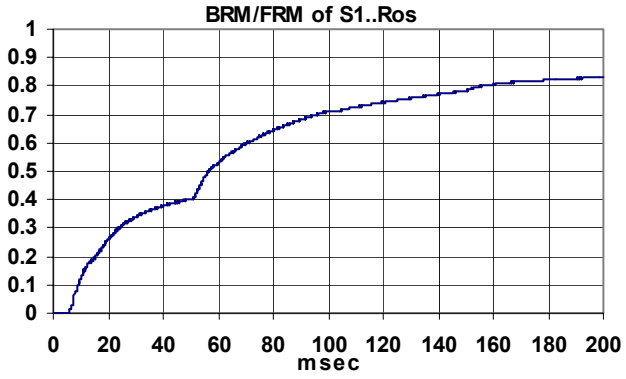


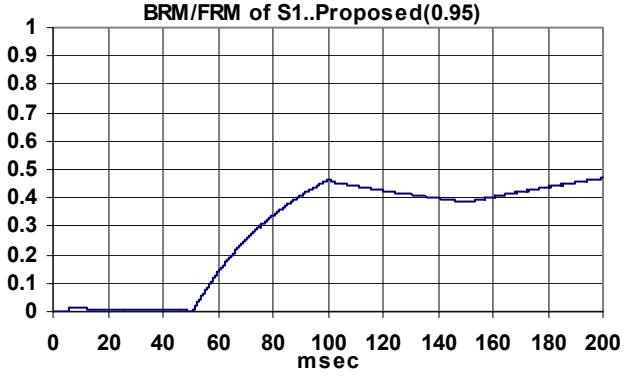


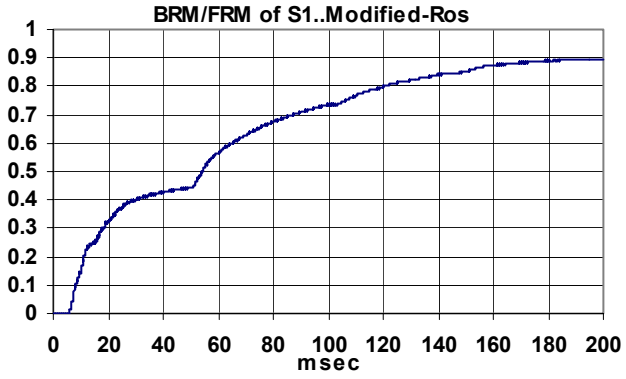
P.L. Config. : RM Ratio(0.95)

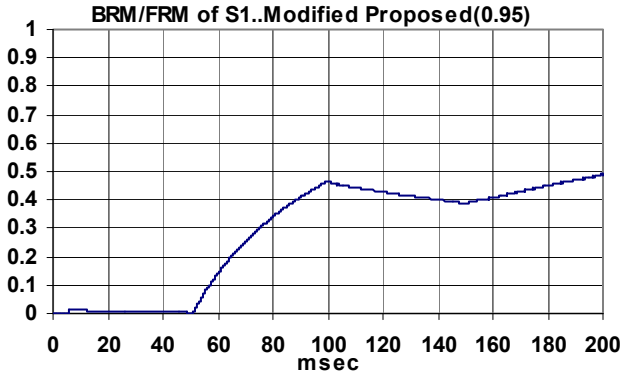












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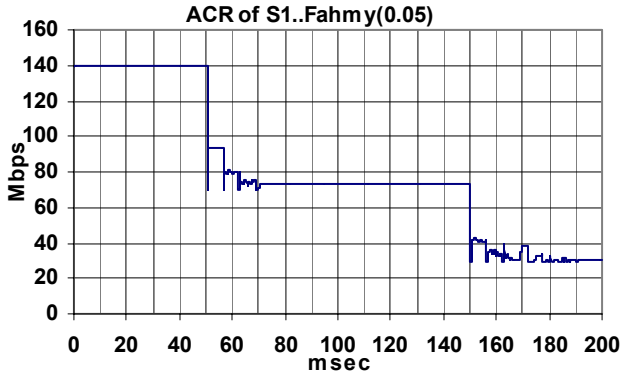
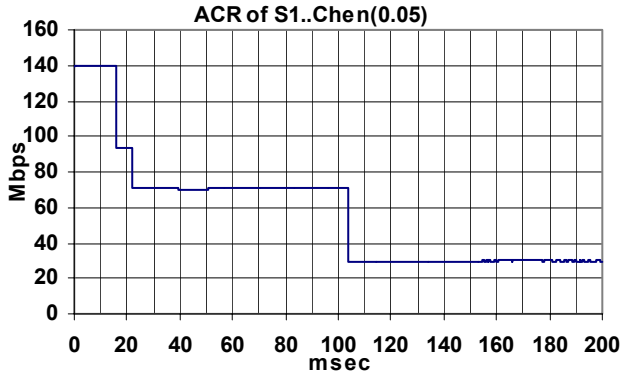
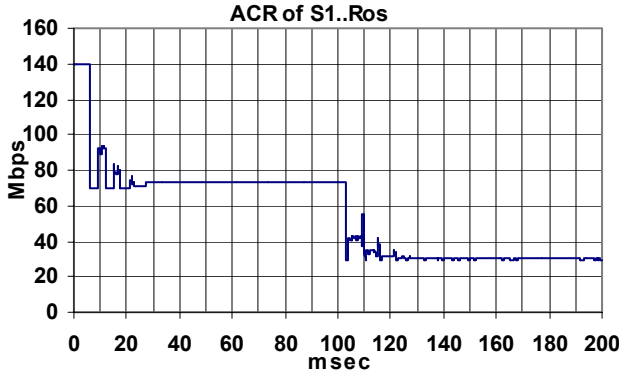
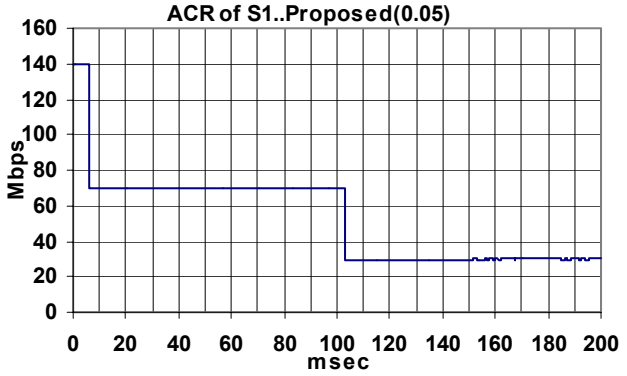
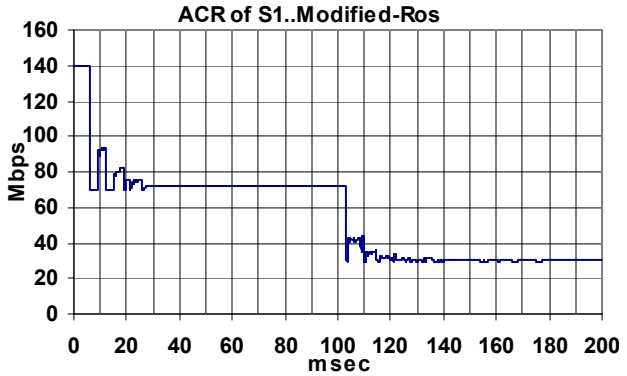
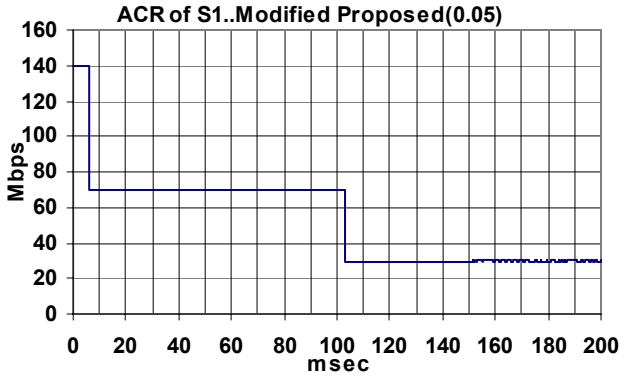




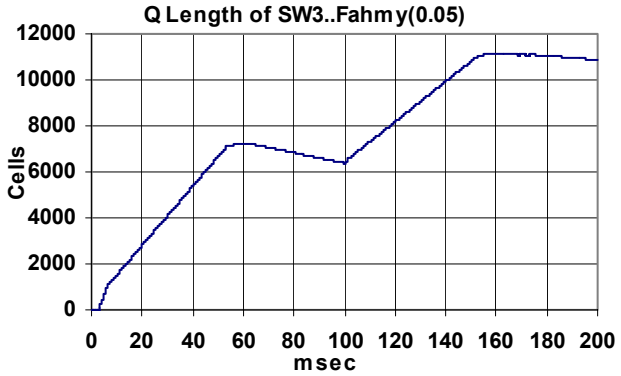


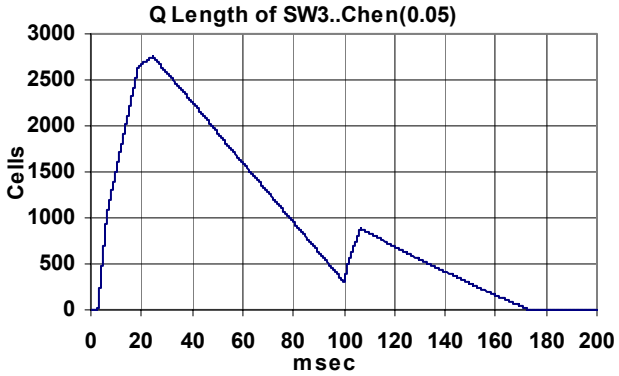


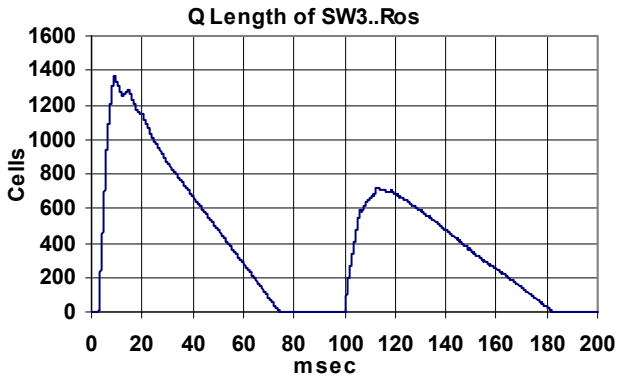


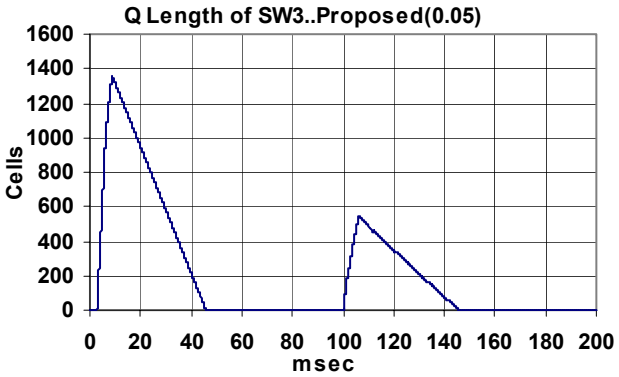


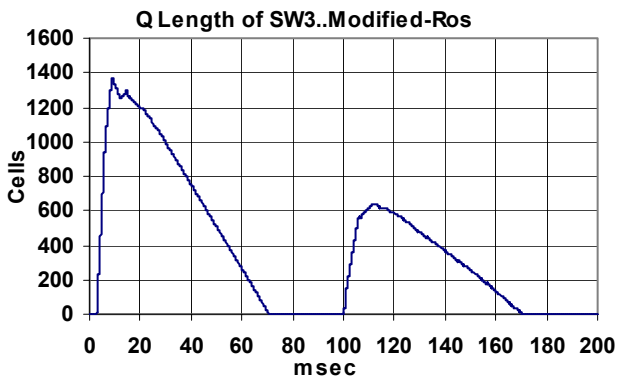
P.L. Config. : Queue Length(0.05)

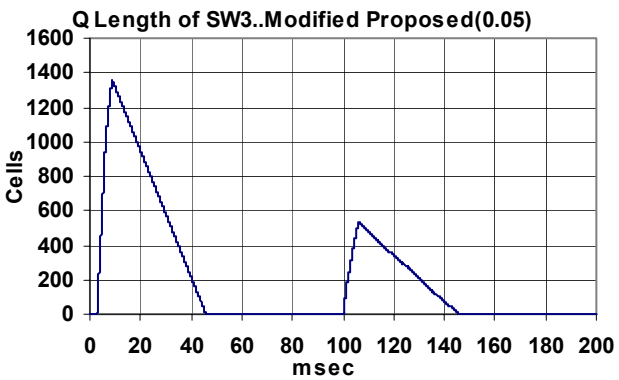




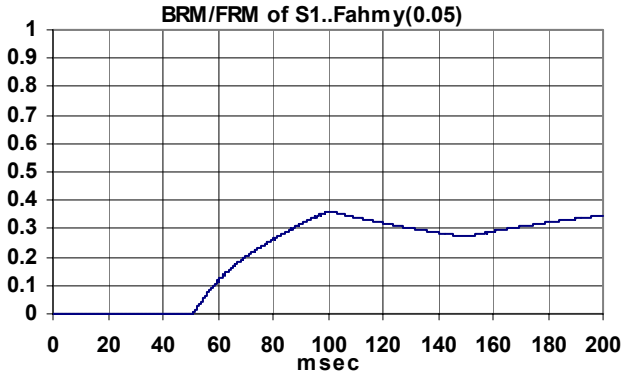


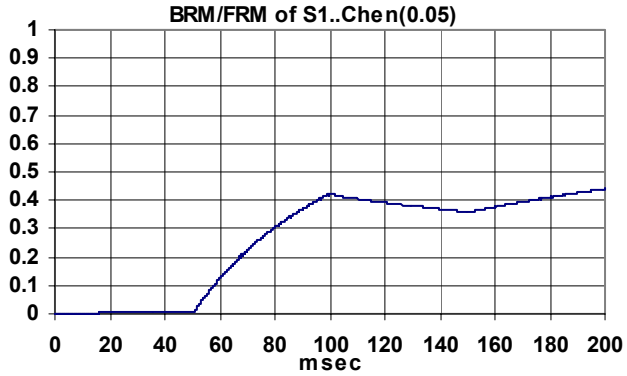


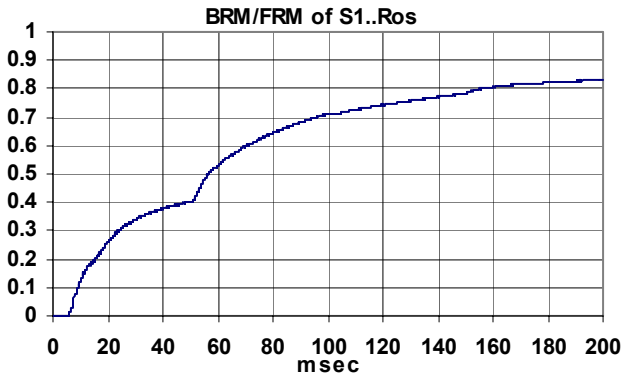


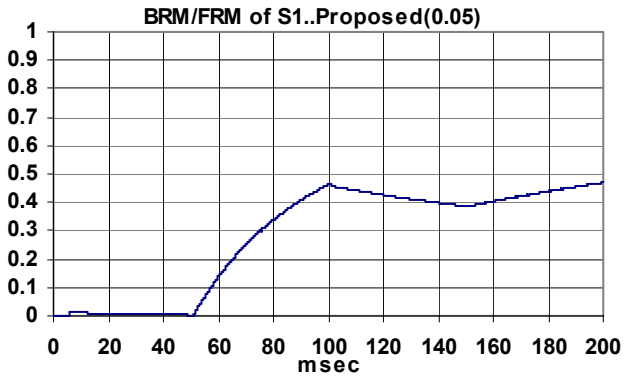


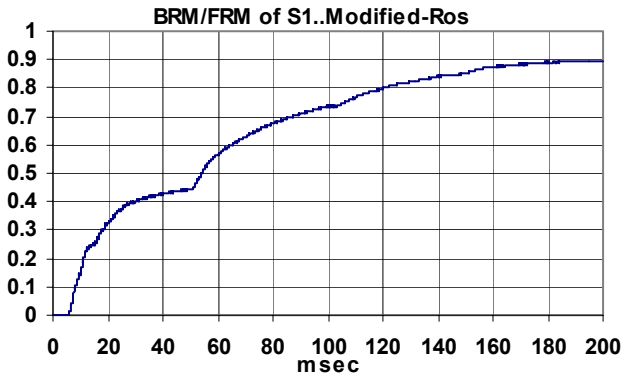
P.L. Config. : RM Ratio(0.05)

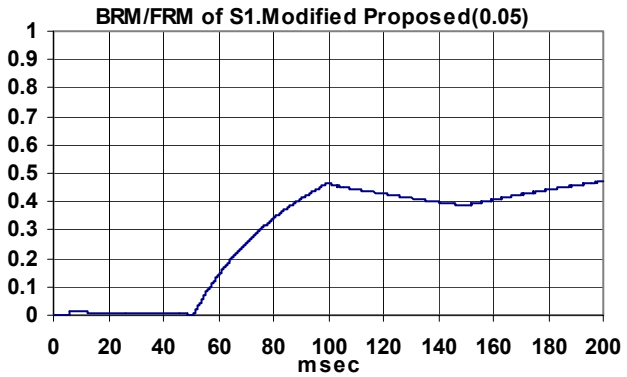




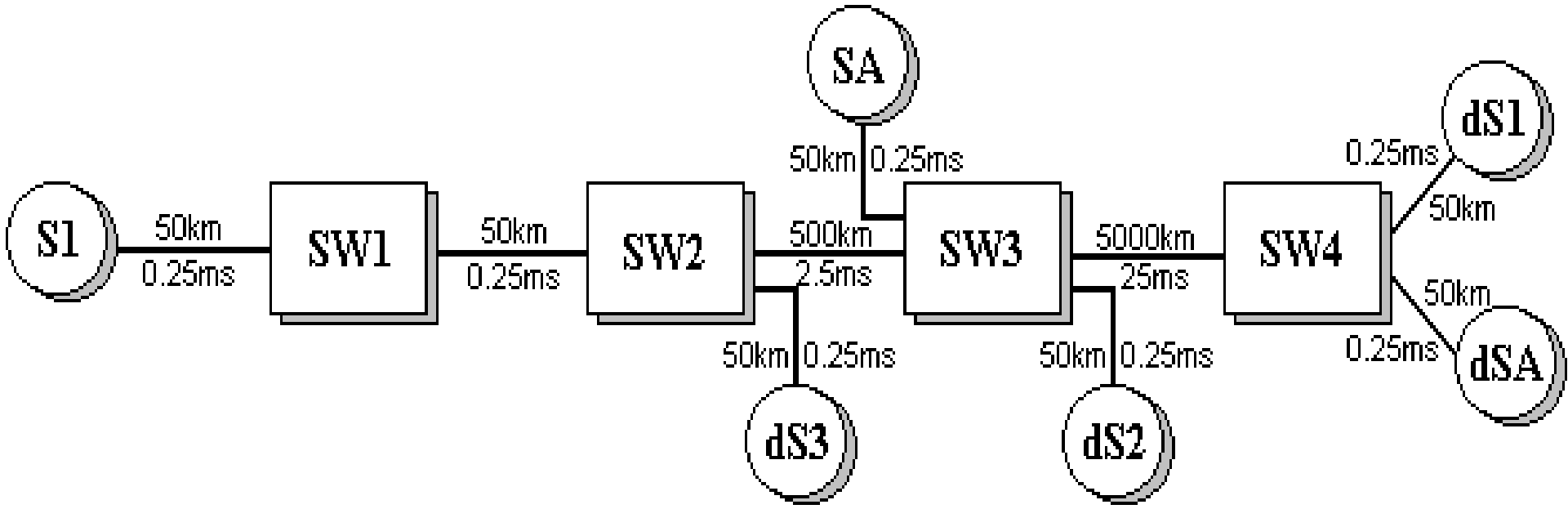






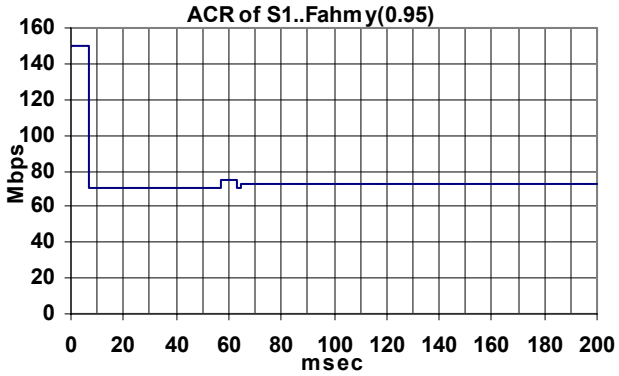


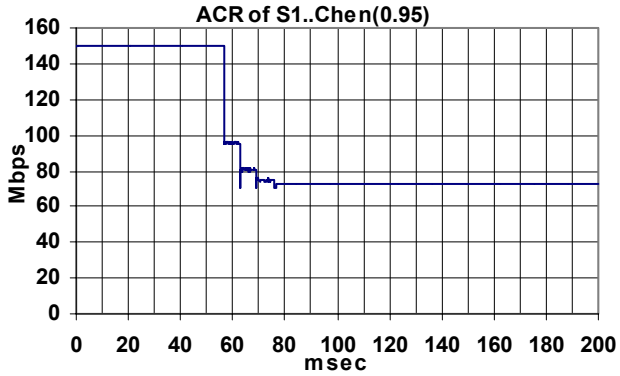
[2] *Chain Configuration*

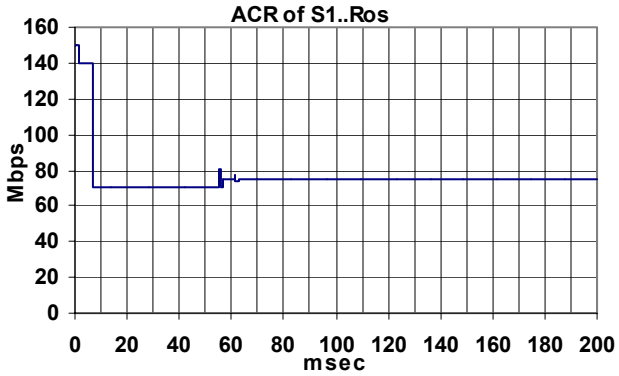


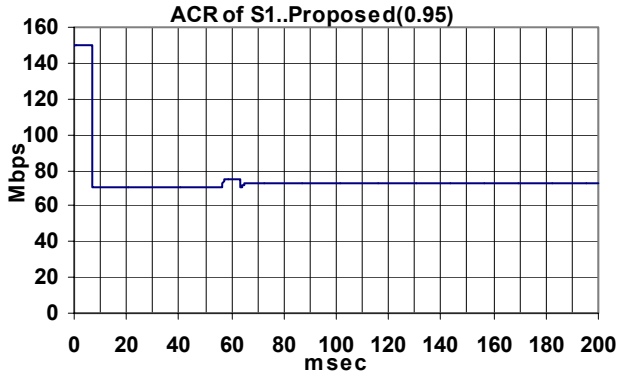
- One ABR P-to-MP : from S1 to dS1,dS2,dS3
- One ABR P-to-P : from SA to dSA
- The link SW3-SW4 is the bottleneck link

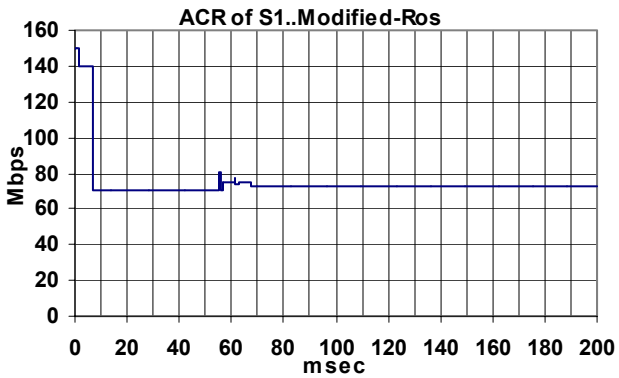
Chain Config. : ACR(0.95)

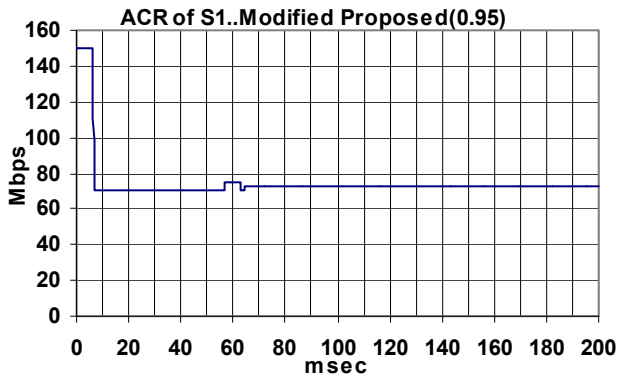




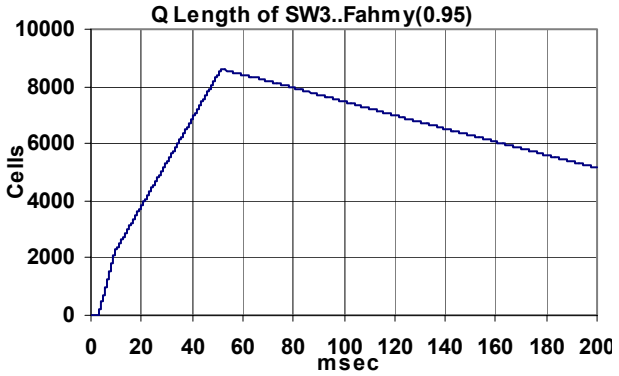


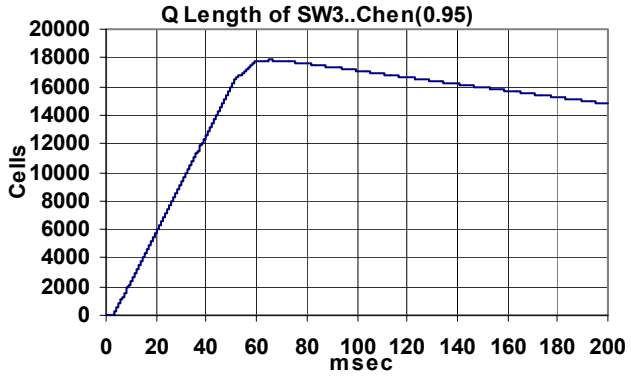


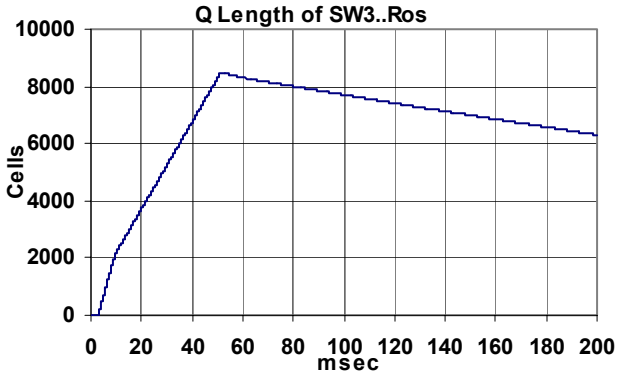


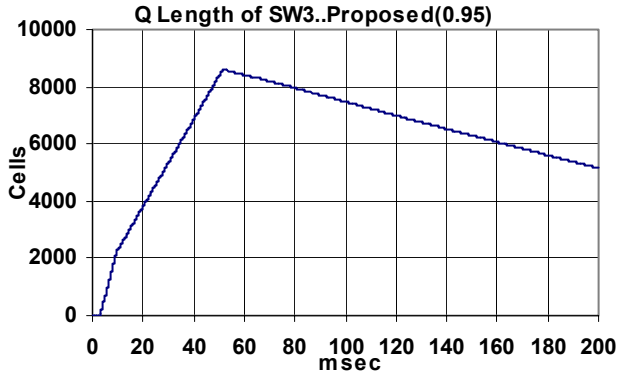


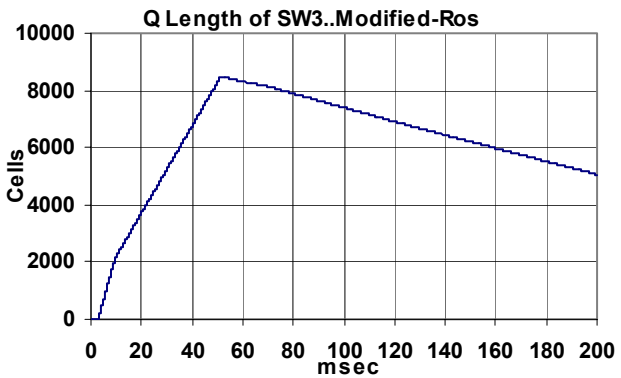
Chain Config. : Queue Length(0.95)

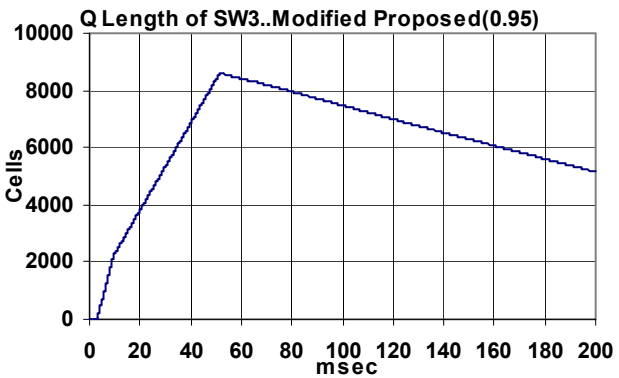




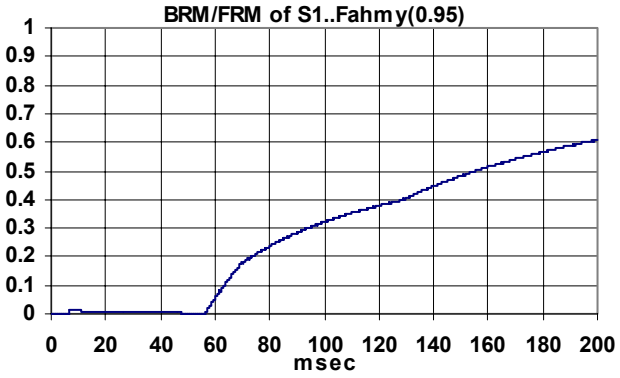


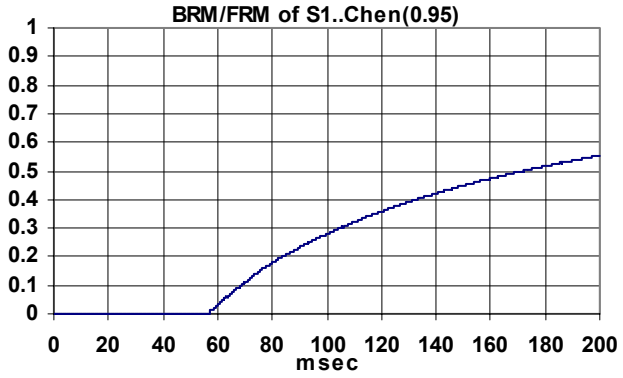


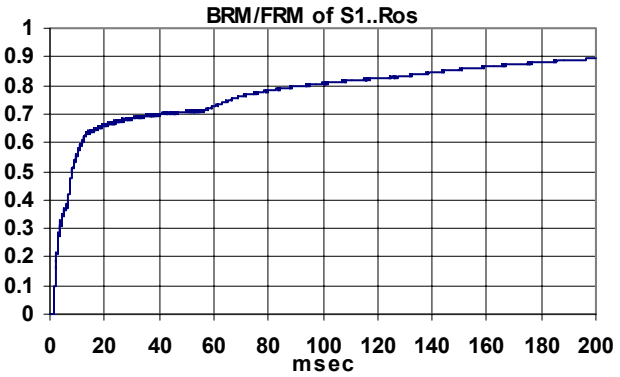


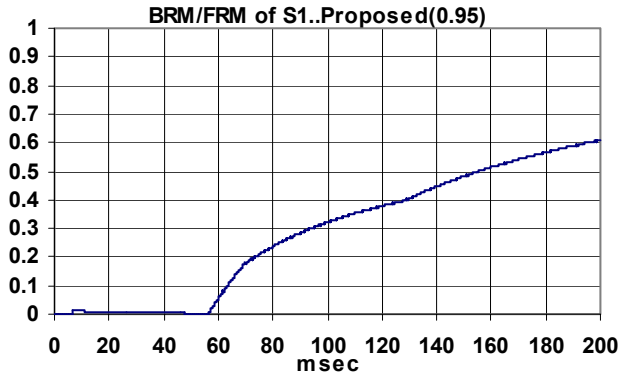


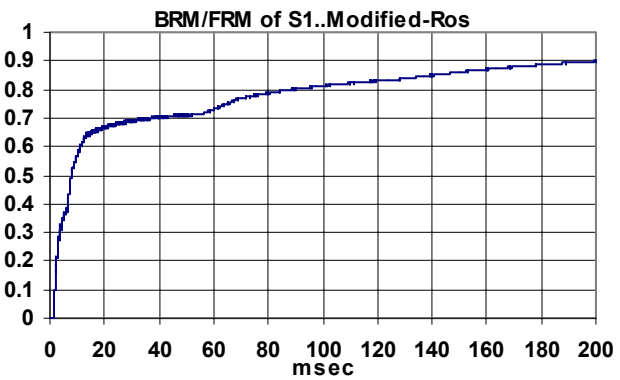
Chain Config. : RM Ratio(0.95)

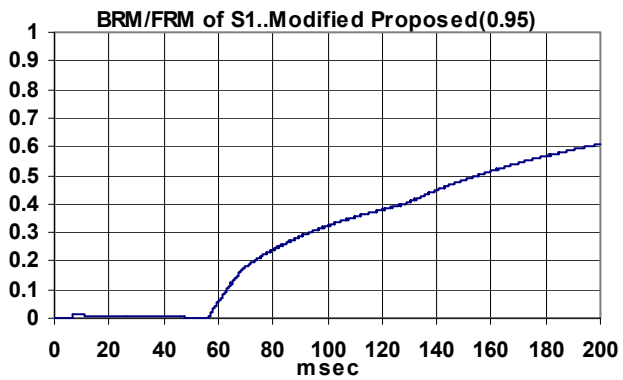




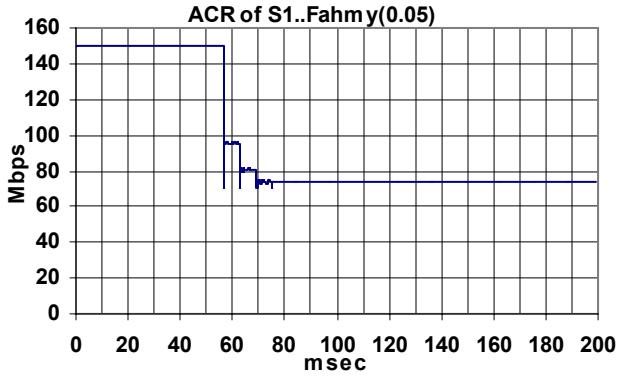


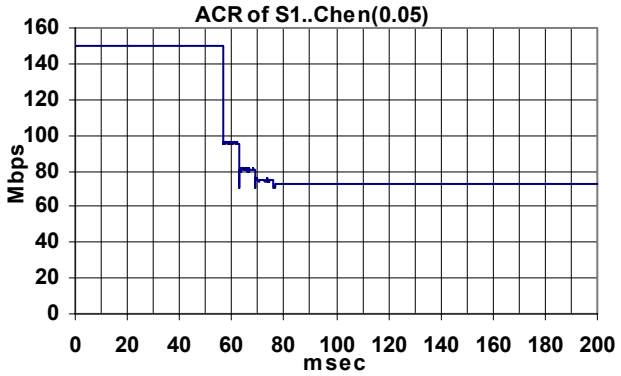


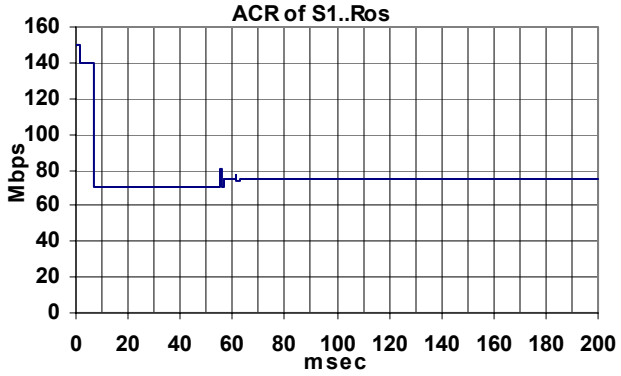


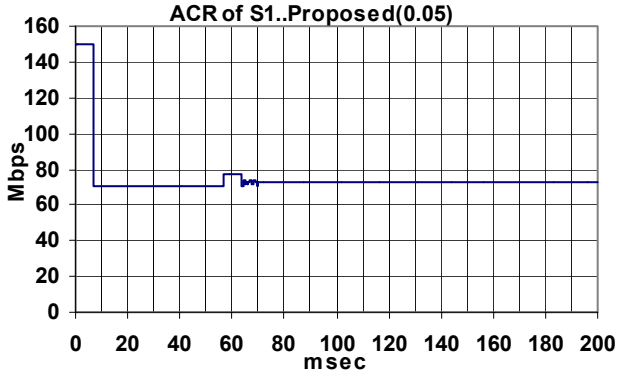


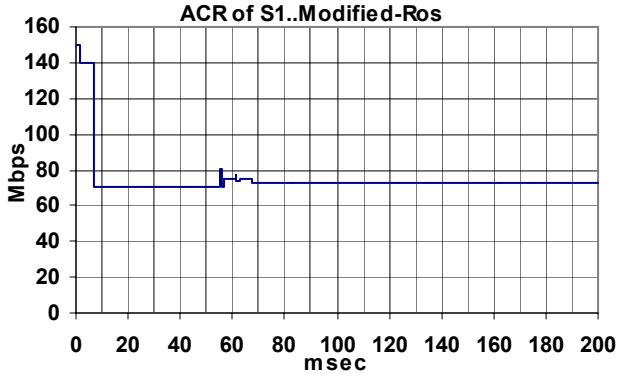
Chain Config. : ACR(0.05)

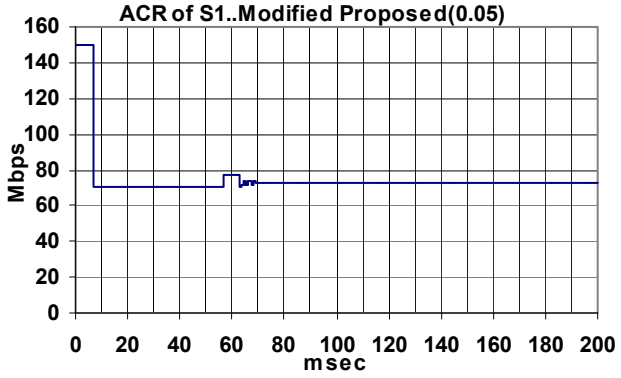




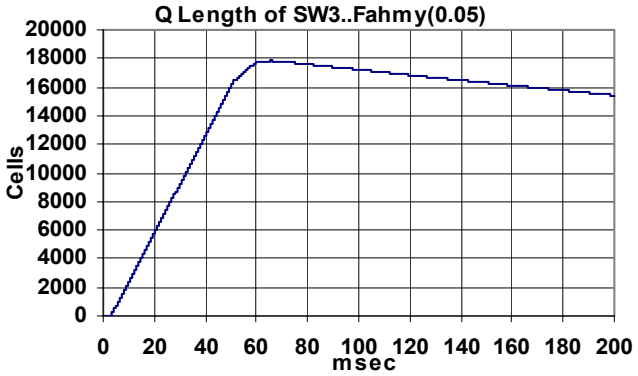


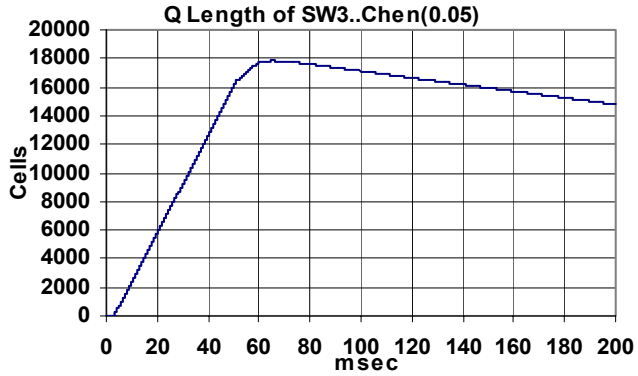


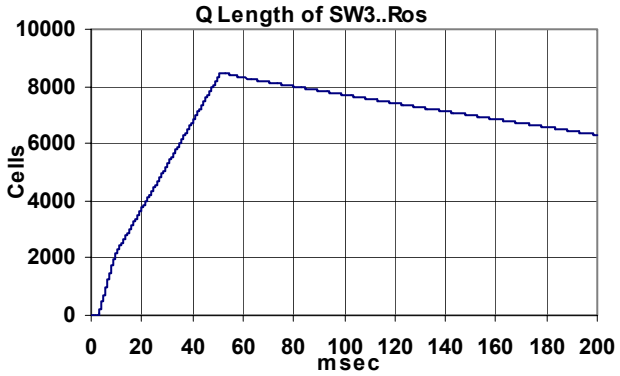


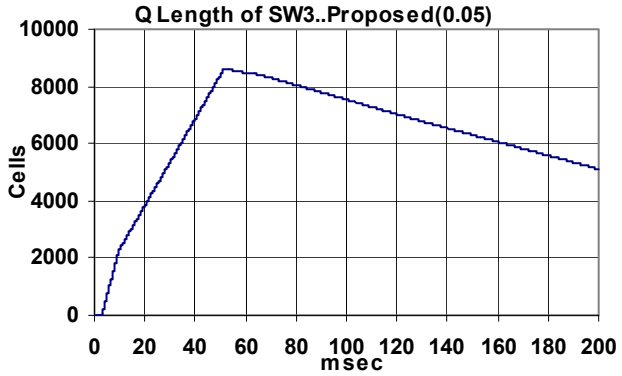


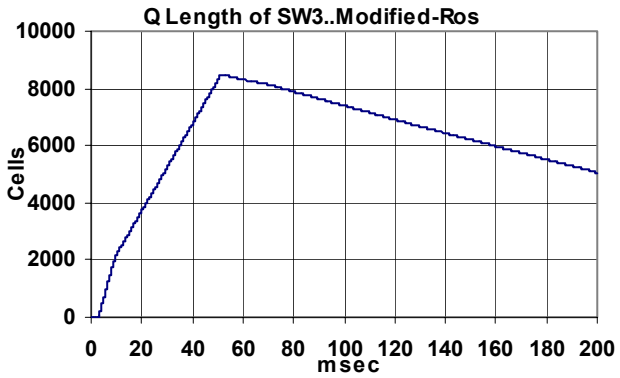
Chain Config. : Queue Length(0.05)

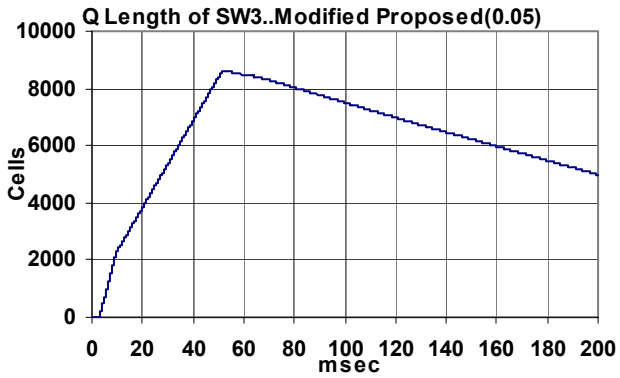




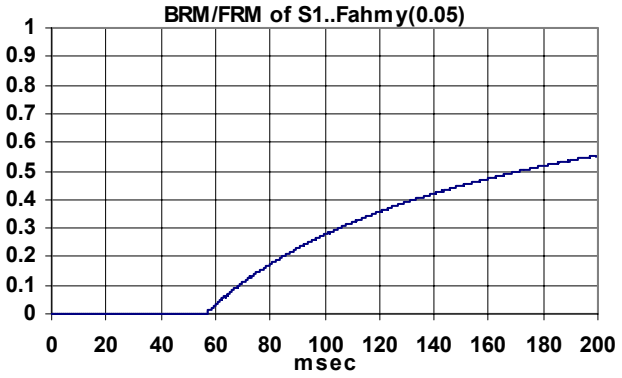


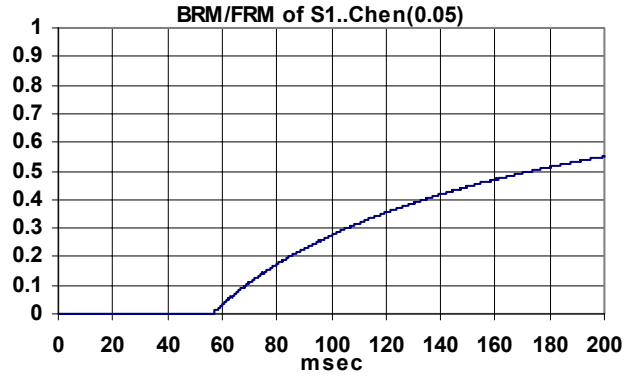


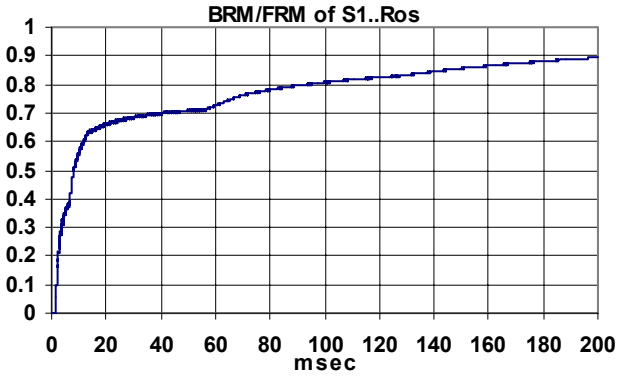


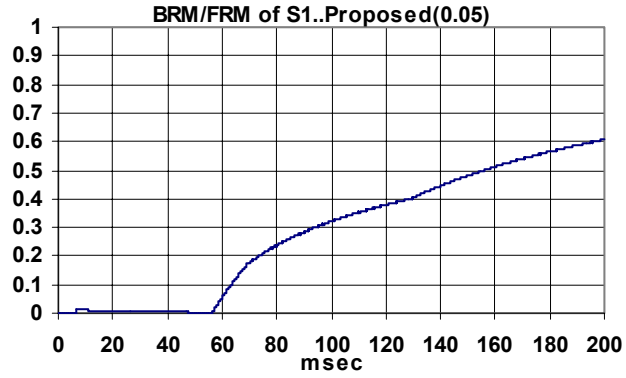


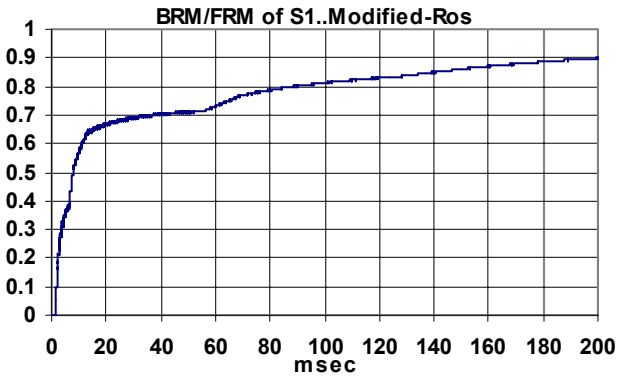
Chain Config. : RM Ratio(0.05)

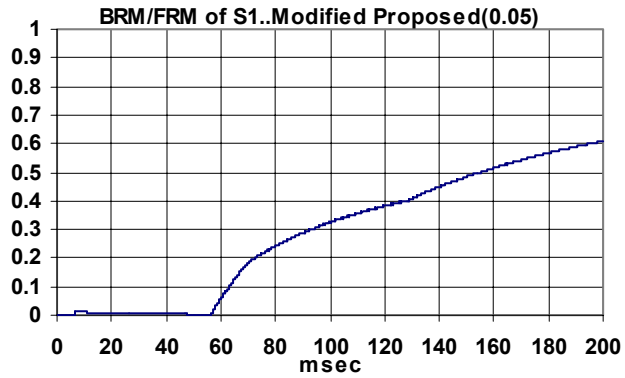




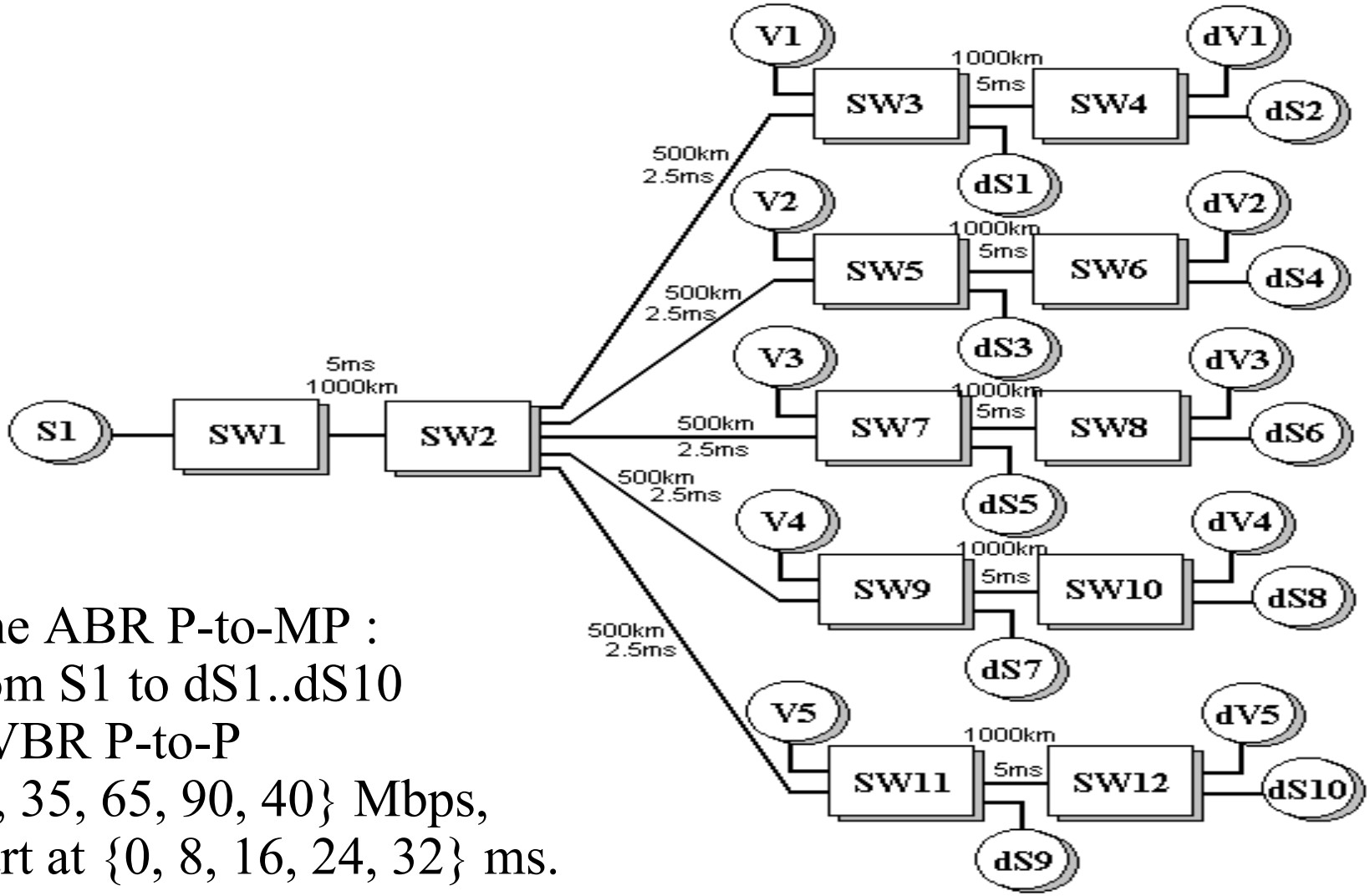








[3] *Jumping-Bottleneck Configuration*

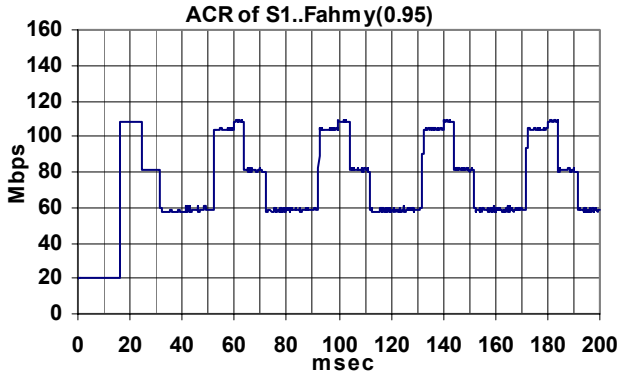


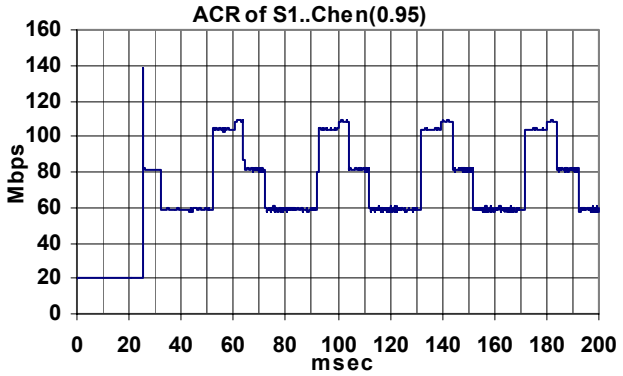
- One ABR P-to-MP :
  from S1 to dS1..dS10
- 5 VBR P-to-P
  {5, 35, 65, 90, 40} Mbps,
  start at {0, 8, 16, 24, 32} ms.

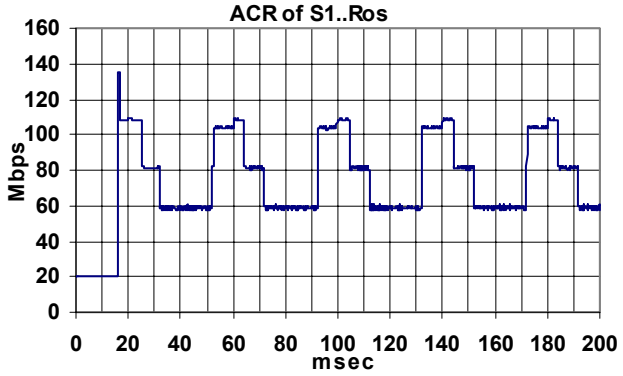
[3] *Jumping-Bottleneck Configuration*

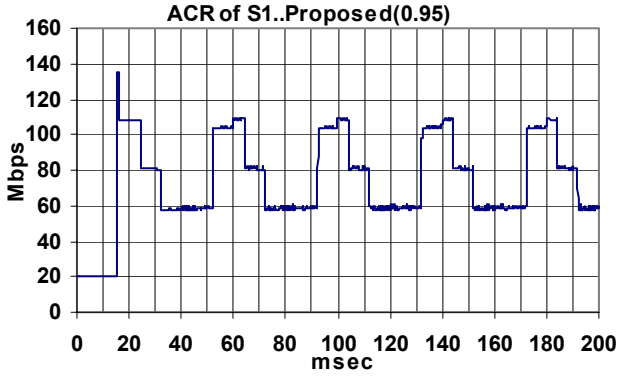
Event No.	Time (ms)	Event	New Bottleneck Switch and Rate
1	0	V1 becomes active	SW3,135.5
2	8	V2 becomes active	SW5,108.5
3	16	V3 becomes active	SW7,81.5
4	20	V1 becomes inactive	SW7,81.5
5	24	V4 becomes active	SW9,59
6	28	V2 becomes inactive	SW9,59
7	32	V5 becomes active	SW9,59
8	36	V3 becomes inactive	SW9,59
9	40	V1 becomes active	SW9,59
10	44	V4 becomes inactive	SW11,104
11	48	V2 becomes active	SW11,104

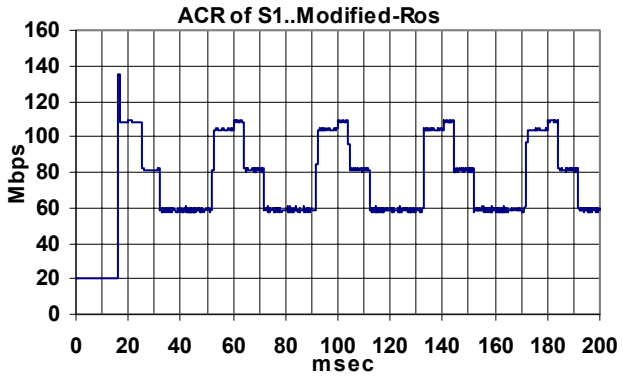
J.B. Config. : ACR(0.95)

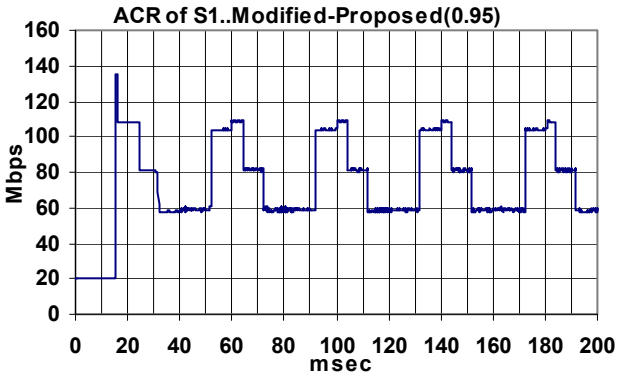




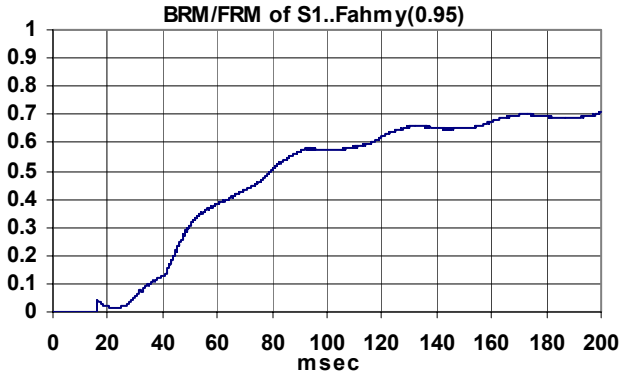


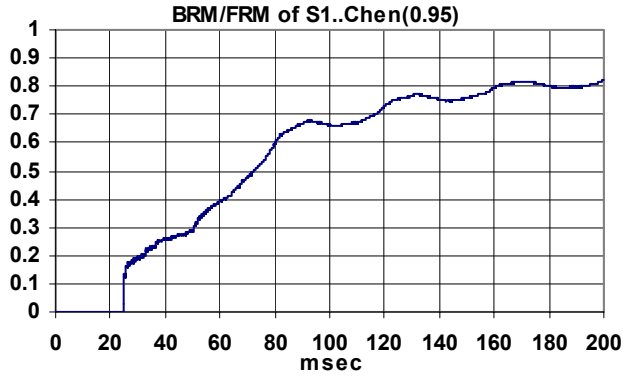


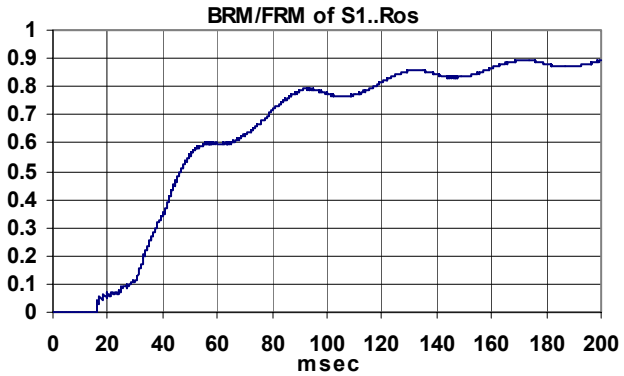


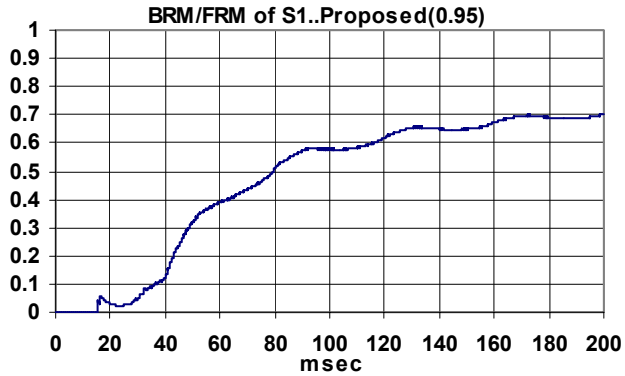


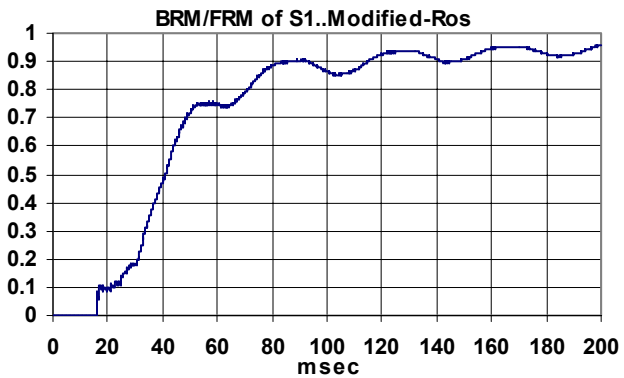
J.B. Config. : RM Ratio(0.95)

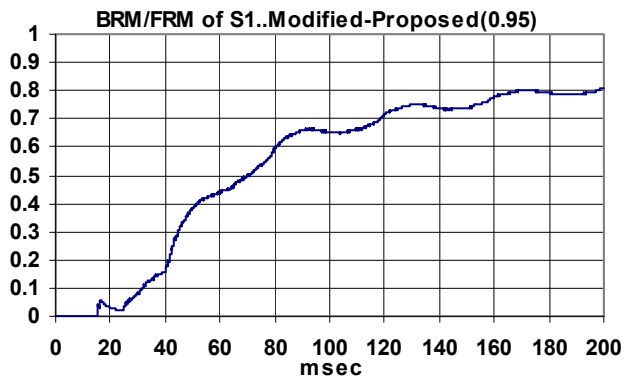




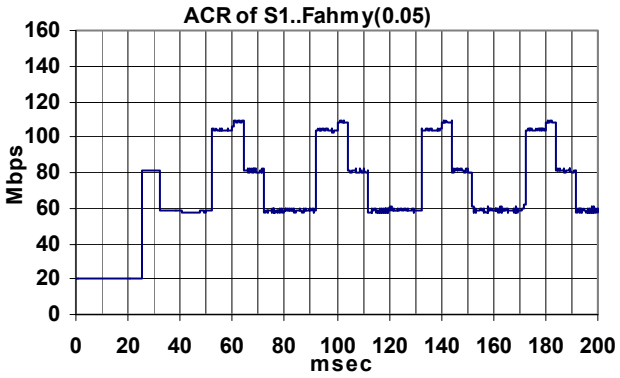


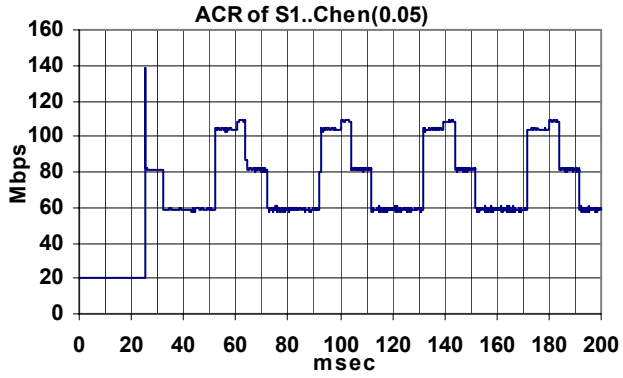


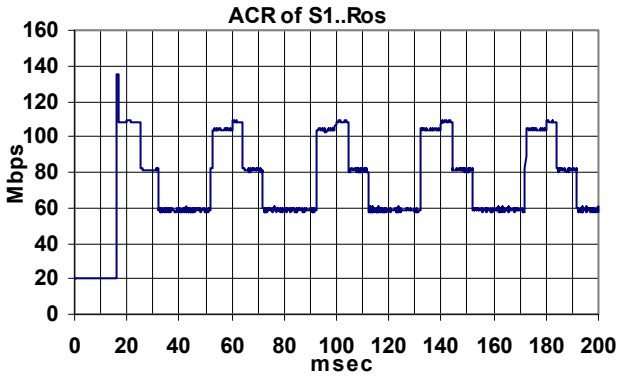


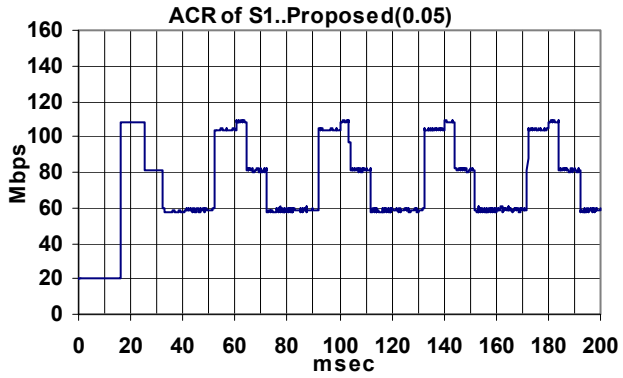


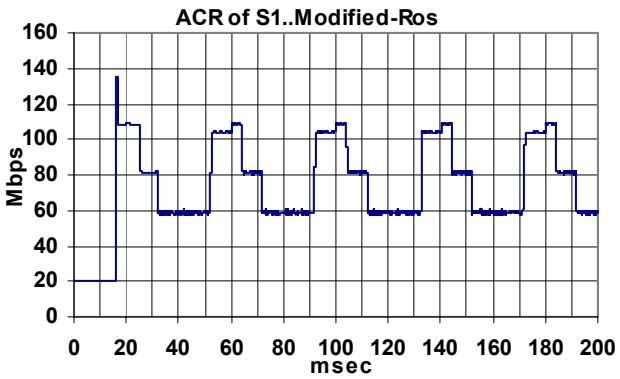
J.B. Config. : ACR(0.05)

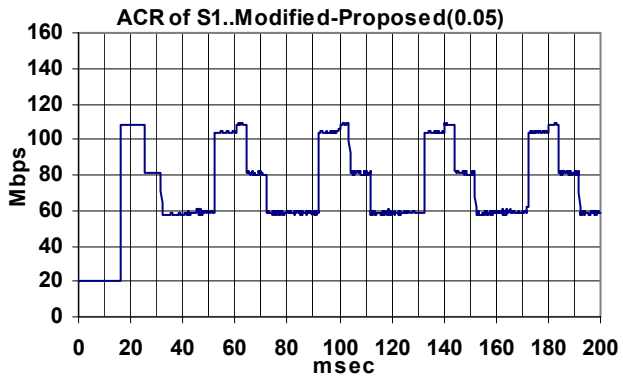




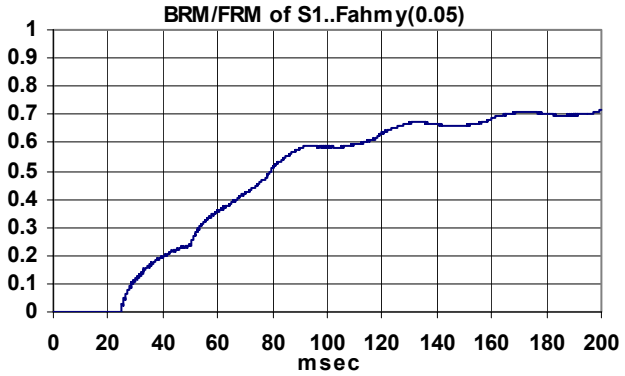


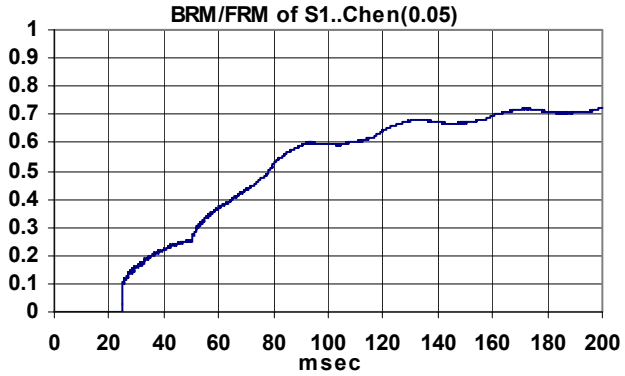


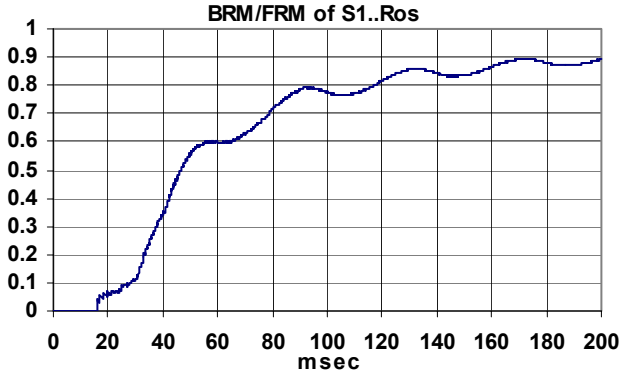


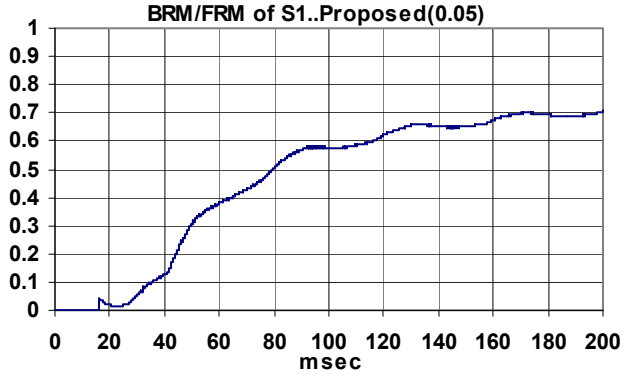


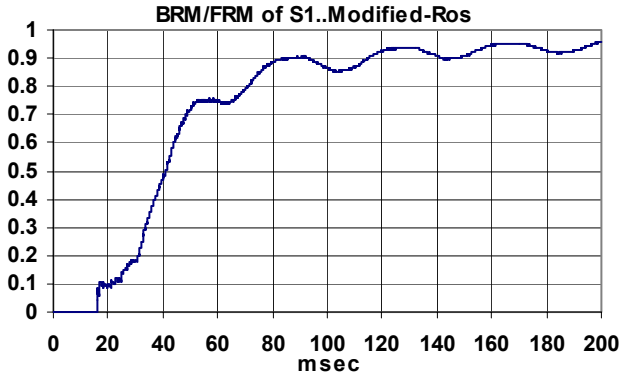
J.B. Config. : RM Ratio(0.05)

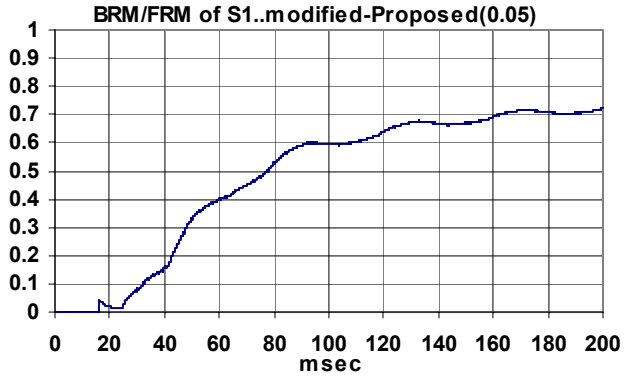












What is the condition to trigger sending a BRM cell ?

1. Wait for all branches to respond [Ren 1996]
2. Time-out [Moh 1997]
3. Fast overload indication + RM ratio control [Sonia 1998]
4. Probabilistic Aggregation [Ammar 1998]
5. Severe overload indication+Probabilistic Aggregation in case of moderate overload [Chen 1999]
6. Bottleneck change [Ros 2000]
7. Severe overload indication+Probabilistic Aggregation in case of moderate overload + RM ratio control **[Proposed]**

Comparison between Algorithms

Algorithm	Fahmy	Chen	Ros	Modified-Ros	Proposed
Implementation Complexity	>Medium	Medium	High	High	>Medium
Transient Response (low threshold)	Slow	Slow	Very fast	Very fast	Fast for overload
Transient Response (high threshold)	Very Fast for overload	Fast for overload	Very fast	Very fast	Very fast for overload
Consolidation Noise	Low	Low	Low	Low	Low
BRM:FRM at root	Lim=1	May be >1	Lim=1	Lim=1 but faster	Lim=1

Conclusions

- Our proposed algorithm doesn't suffer from consolidation noise problem.
- The proposed algorithm exhibits a fast transient response with accurate feedback in case of low and high thresholds (threshold-independent).
- Due to the fast transient response, the initial queue length is low and bounded even in the worst-case load situations like high ICR.
- The overhead of local congestion check is reduced in our proposed algorithm.
- The new RM ratio control method has the effect of accelerating the convergence of the RM ratio to one.
- The improvement of the new method is high, as the ability of the algorithm to send more extra BRM cells, or the rate of change of network conditions, is high.

Future Work

- Adding a simple and efficient mechanism for handling non-responsive branches.
- Examining the effect of the VS/VD (Virtual Source/Virtual Destination) option on the point-to-multipoint connections and on the feedback consolidation algorithms.
- The performance of a network with different algorithms at the different branch points, and point-to-multipoint VCs that branch at several branch points with different algorithms, will need further study if a consolidation algorithm is not standardized.
- Examining the effect of ABR source parameters and ABR source rules on multipoint connections and developing formulae and guidelines for setting these parameters to achieve the best performance.