CIS-6930: Distributed Multimedia Systems

Enhancing aggregate QoS for video streaming

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OUTLINE

- Some Key Terms
- Introduction
- MPEG Video Dispersion Strategies
- Altruistic Routing
- ALTRA – based Video Streaming
- Conclusion

KEY TERMS

- Diff –Serv (Differentiated Service architecture by IETF)
- MPLS (Multi-Protocol Label Switching)
- LSP (Label Switched Paths)
- Ingress Node
- Egress Node

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INTROUCTION

- Recent times has seen a proliferation of multimedia applications.
- Hence , we need a network infrastructure that can meet the QoS requirements of the multimedia traffic.
- Multimedia Traffic requirements : Guaranteed end to end quality and high bandwidth requirement.

INTROUCTION (2)

- MPEG occupies large portion of the Internet traffic, hence, efficient transport mechanisms for MPEG traffic are crucial.

- In this paper, authors propose a set of multi-path streaming models for MPEG video traffic transmission and a routing scheme to search for altruistic multiple paths in the network for aggregate video streaming.

INTROUCTION (3)

- Due to decoding dependencies, MPEG's frames are very sensitive to packet loss/error. Thus, routing for delivering MPEG streams is important.
- The approach proposed by the authors employees existing application level knowledge of the MPEG video structure
- It does not requiring new video compression algorithms or additional bandwidth.

SYSTEM MODEL

- The network model assumes :
  - Diff-Serv aware MPLS infrastructure
  - Number of available LSPs (paths) between the ingress node and the egress node.
  - Each LSP has attributes such as path delay, bandwidth, and loss rate.
  - Aggregates of MPEG video streams are dispersed into several LSPs at the ingress node before it is sent to the egress node.

SYSTEM MODEL(2)

- The network model assumes:
  - Service differentiation for each packet is determined at the ingress according to the proposed dispersion models.

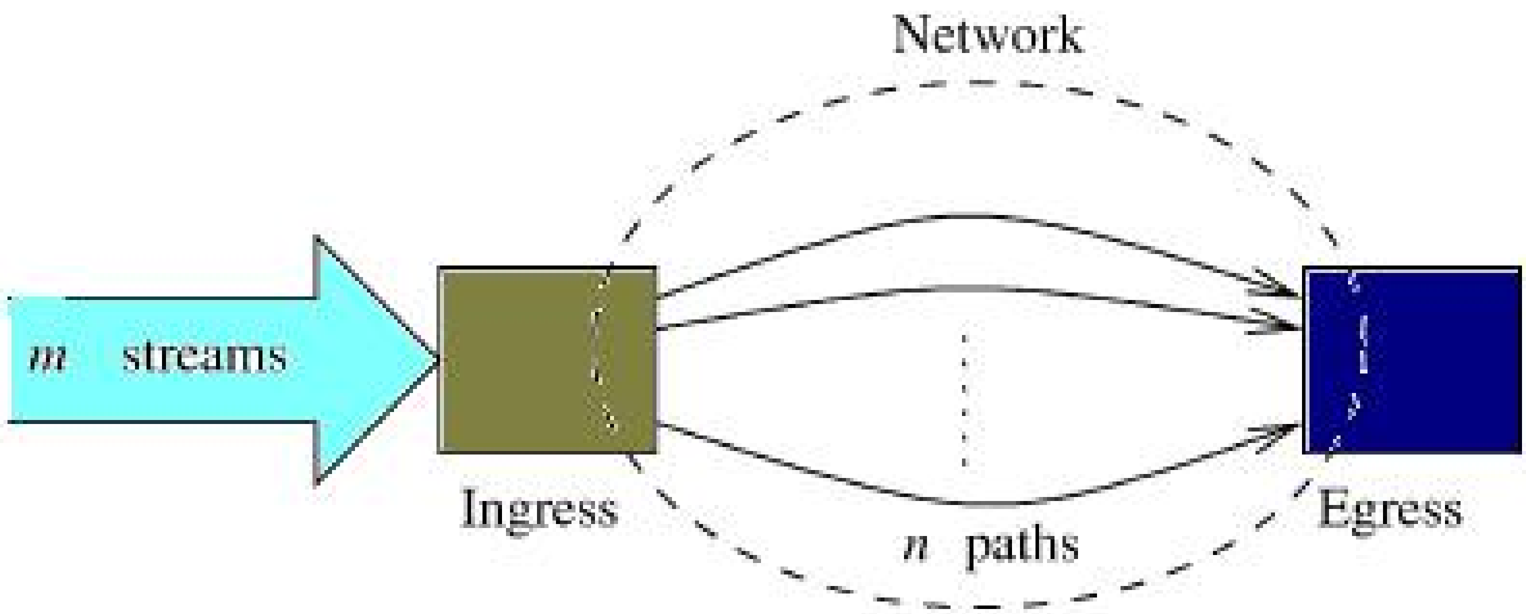

Fig. 2. Network model for traffic dispersion.

SYSTEM MODEL(3)

- The network model assumes :
  - MPEG video streams are composed of groups of picture (GOP)2.
  - GOP is defined by two parameters -N and M.
    - N - distance between two I-frames. (Also the # of frames in GOP)
    - M - distance between two anchor (I or P) frames.

SYSTEM MODEL(4)

- Each GOP consists of one I-frame (N-M)/M P-frames, and (N(M-1))/M B-frames.
- Authors assume for simulation that a B-frame can usually fit into a single packet, each I-frame can fit into 8 packets and each P-frame can fit into 3 packets.
- To measure performance of the proposed models, authors define these metrics:

SYSTEM MODEL(5)

- average frame damage rate : # of damaged frames at the egress node divided by the total # of transmitted frames at the ingress node.
- average effective frame rate :
- In the following sections, if model mi has an ‘average effective frame rate’ of ri and model mj has an ‘average effective frame rate’ of rj, then the improvement of mj over mi is defined as: Improvement = (rj – ri)/ ri

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DISPERSION STRATEGIES

- Authors propose five MPEG video dispersion strategies :

- Packet - Based Dispersion
  - Video streams are mixed and treated packet by packet.
  - This mixed sequence is dispersed into the available paths one by one.
  - Two schemes can be implemented for this strategy: round robin or weighted round robin.

DISPERSION STRATEGIES(2)

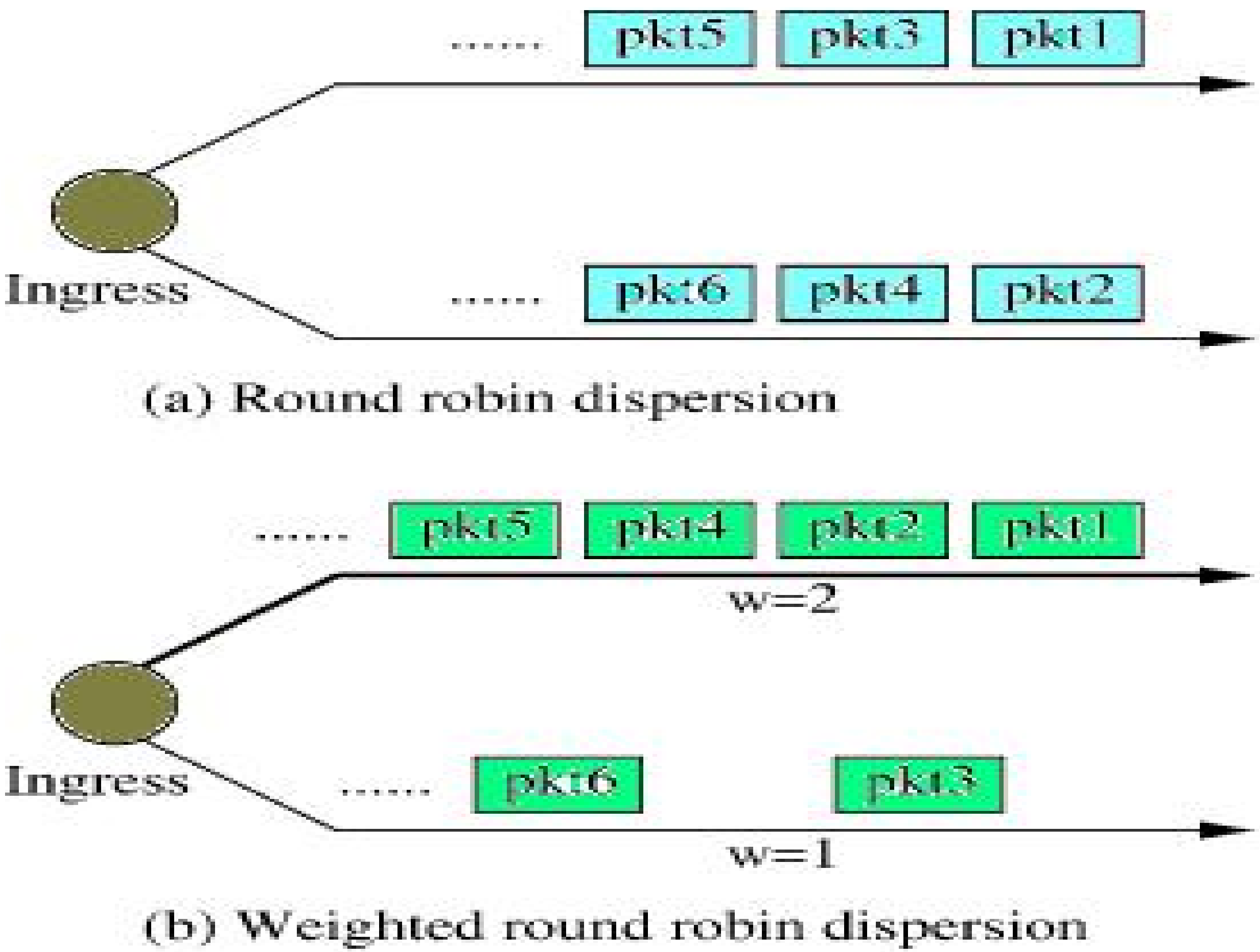

Fig. 3. Packet-based dispersion.

DISPERSION STRATEGIES(3)

- Frame - Based Dispersion
  - Packets belonging to a frame (I,P, or B) are transmitted as a unit along a path.

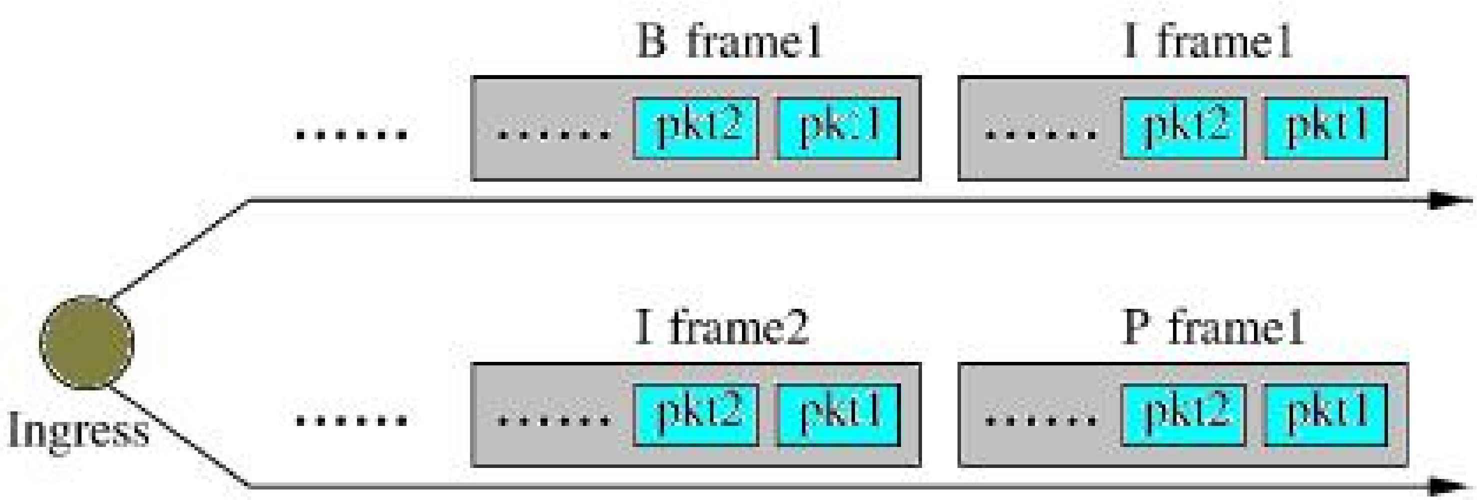

Fig. 4. Frame-based dispersion.

DISPERSION STRATEGIES(4)

- Individual frames belonging to a GOP might traverse different paths.

- Since one lost packet will damage the frame it belongs to, this approach this reduces the number of frames affected. in case of a burst of packet loss.

DISPERSION STRATEGIES(5)

- GOP - Based Dispersion
  - In this model, frames belonging to a GOP are transmitted along the same path.

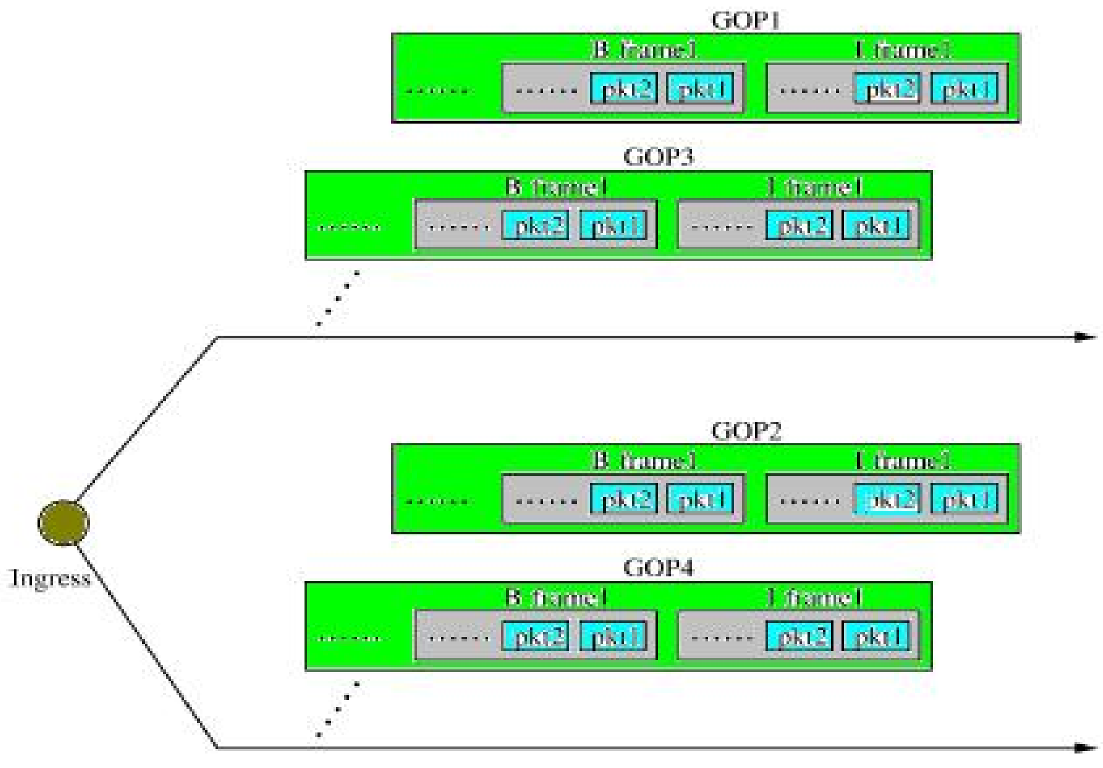

Fig. 6. GOP-based dispersion.

DISPERSION STRATEGIES(6)

- Since a GOP is at higher logical data block level w.r.t frame, this approach reduce damage propagation and avoids massive frame errors

- This is because, in case of burst errors over several frames it is better if all these erroneous frames belong to a single GOP rather than a different GOPs.

- GOP-based model can improve quality by about 5–13% as compared to previous models.

DISPERSION STRATEGIES(7)

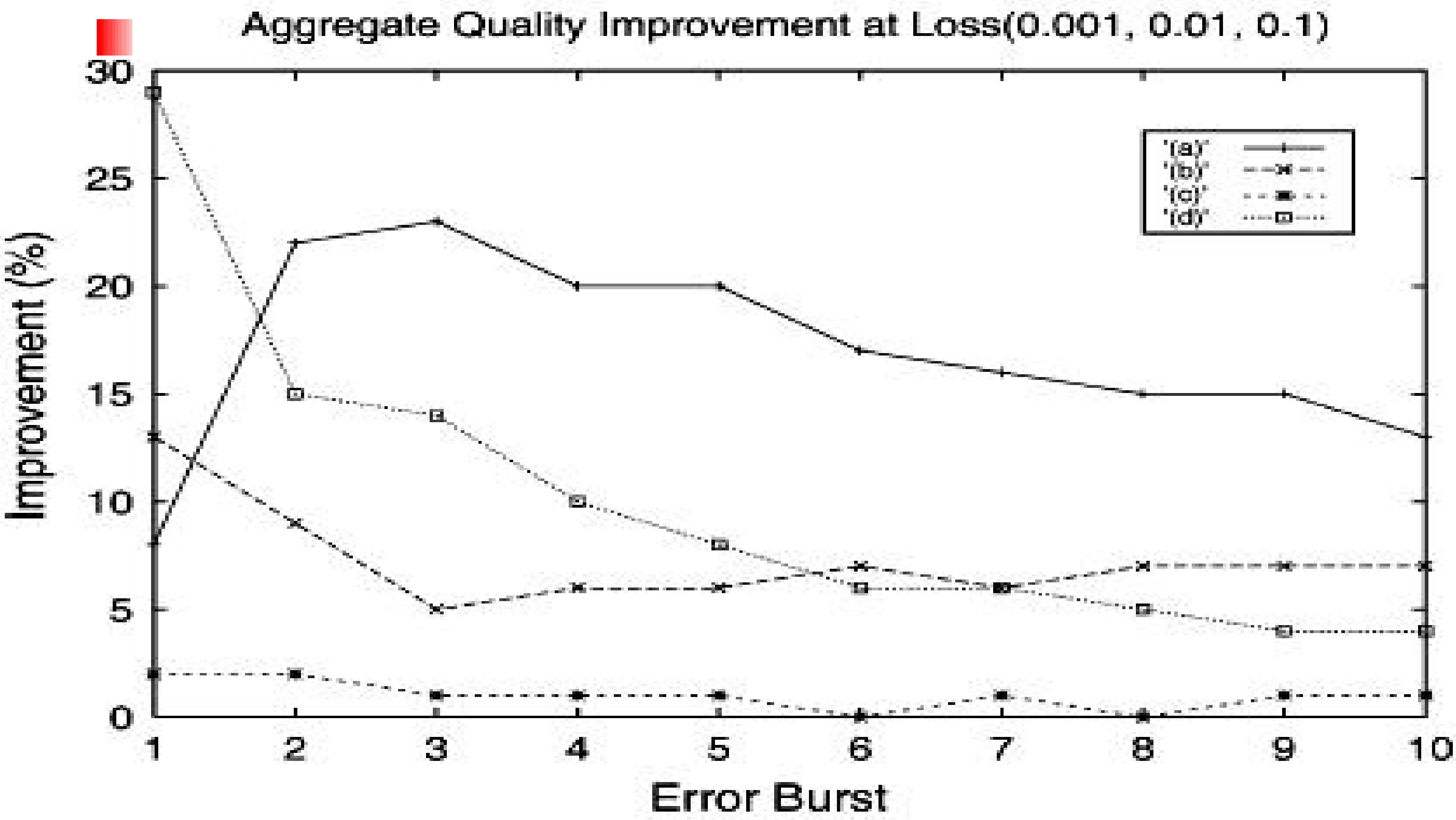

Fig. 5. Aggregate quality improvement at Loss(0.001, 0.01, 0.1).

DISPERSION STRATEGIES(8)

- Stream - Based Dispersion
  - This model disperses the aggregate traffic based on individual streams.

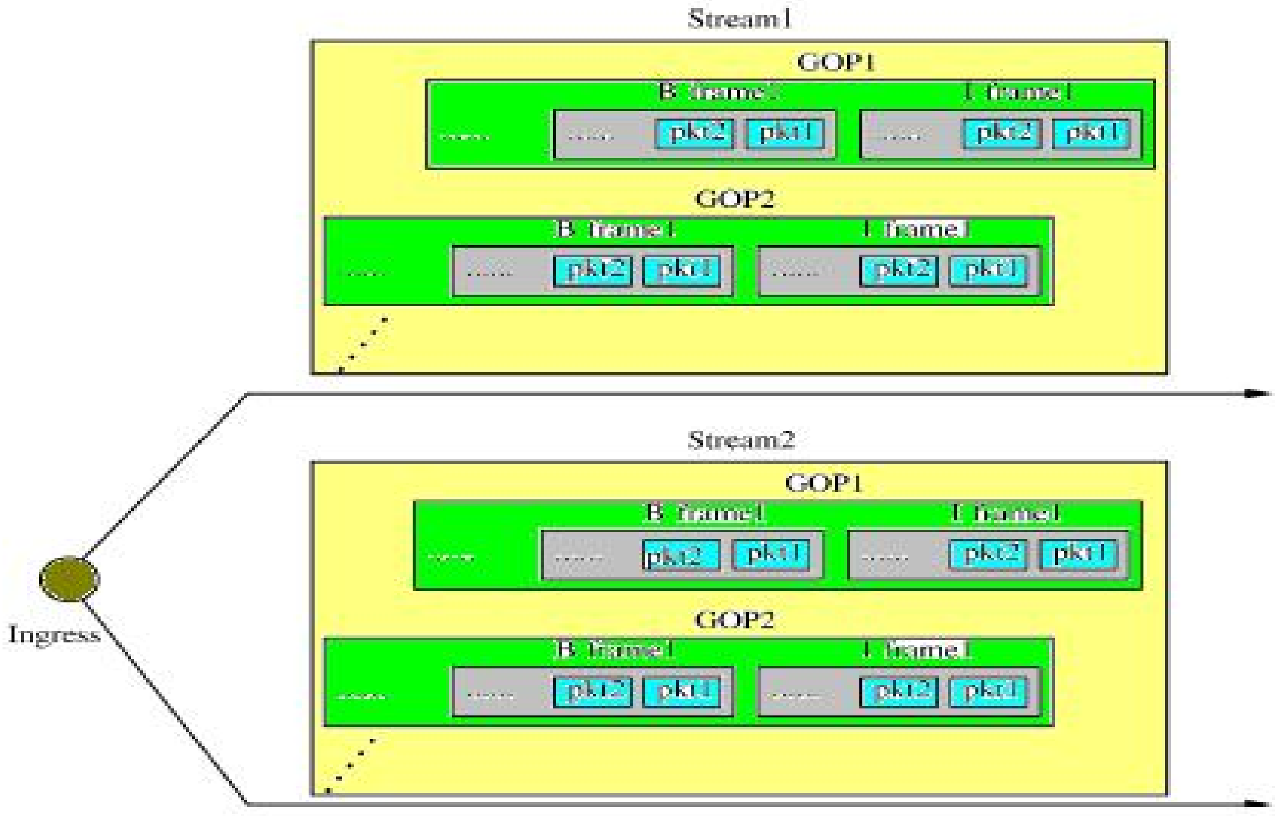

Fig. 7. Stream-based dispersion.

DISPERSION STRATEGIES(9)

- Since a sequence/stream is the largest MPEG video object, this model has a higher error resistant capability than all previous models.
- In the previous graph , we noted that the stream based and GOP Based dispersion strategies have very similar performance.
- The quality improvement is no more than 2%, because frame damage has low probability of being carried over to other GOPs' frames.

Dispersion Strategies(11)

- The stream-based dispersion has the disadvantage of unbalanced stream quality.
- As, we saw in the graph, all other models have a negligible unbalanced performance, the stream-based model has a very high performance variance.
- Hence, GOP based dispersion is better approach than the stream based model because although it has a very similar performance without the above disadvantages of unbalanced stream quality.

Dispersion Strategies(12)

- Priority - Based Dispersion
  - In this approach , MPEG stream is dispersed based on relative importance of the frames.

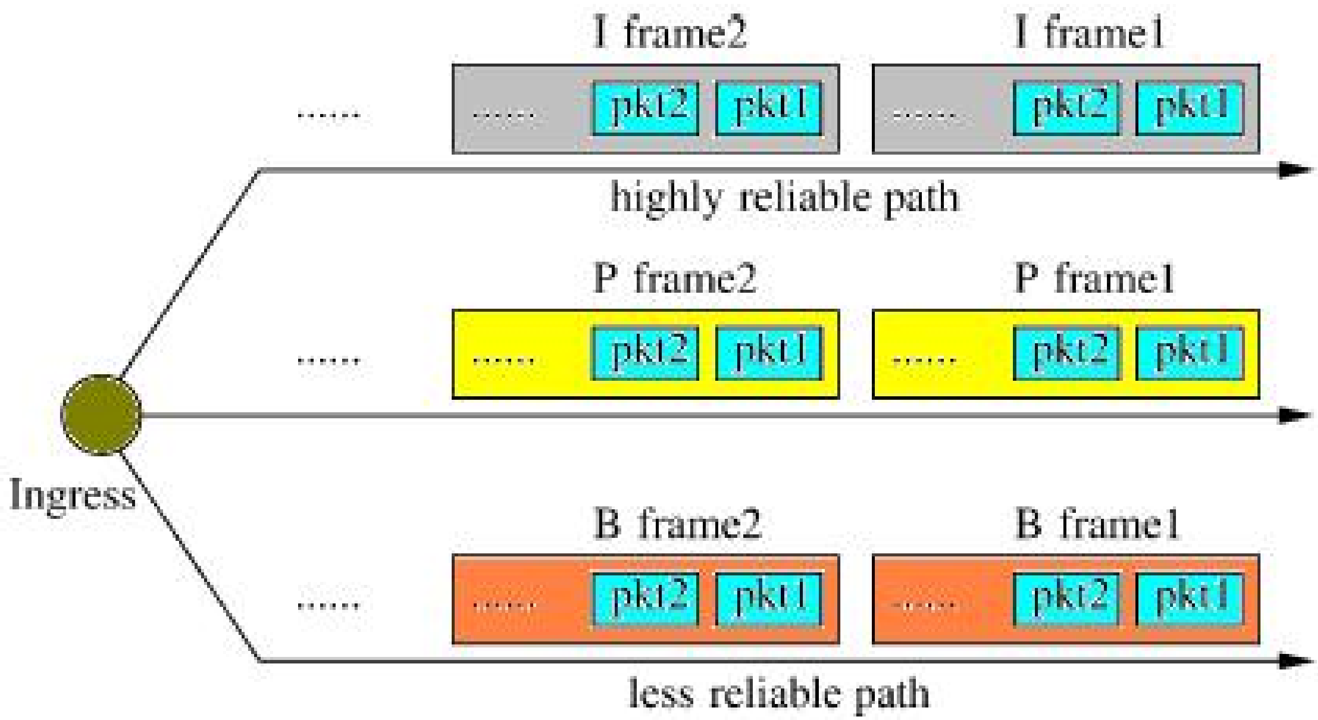

Fig. 9. Priority-based dispersion.

Dispersion Strategies(13)

- In MPEG's encoding algorithm, I-frames are the most important and B-frames are the least important frames.
- But, not all P-frames are of equal importance. Within a GOP, errors in the nth P-frame will propagate to the (n+1)th P-frame. Hence, the nth P-frame is more important than the (n1)th P-frame.
- Hence, authors define the priorities in a GOP as:

Comparison of Dispersion Strategies

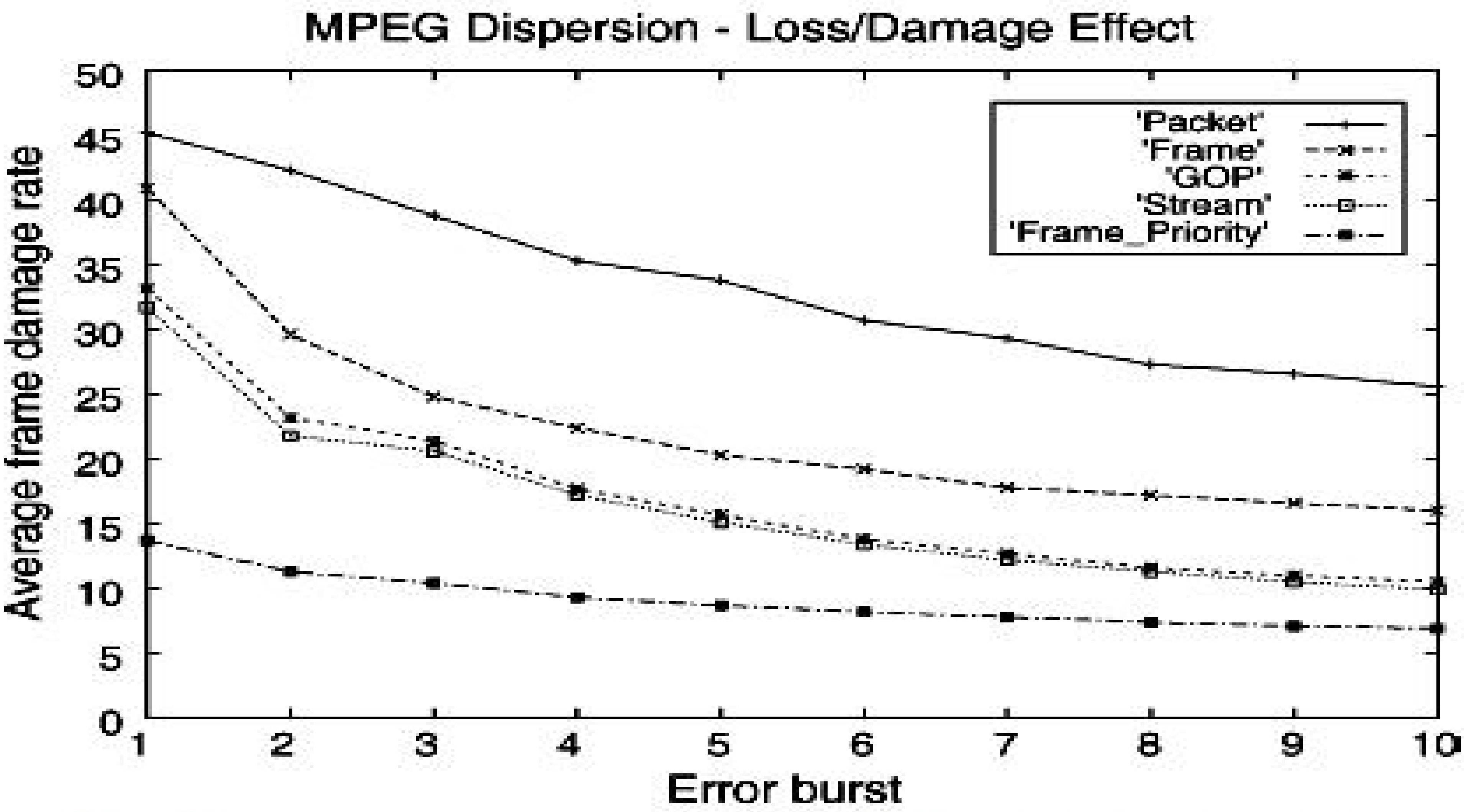

Fig. 10. Average frame damage rate, with Loss(0.001, 0.01, 0.1).

Comparison of Dispersion Strategies(1)

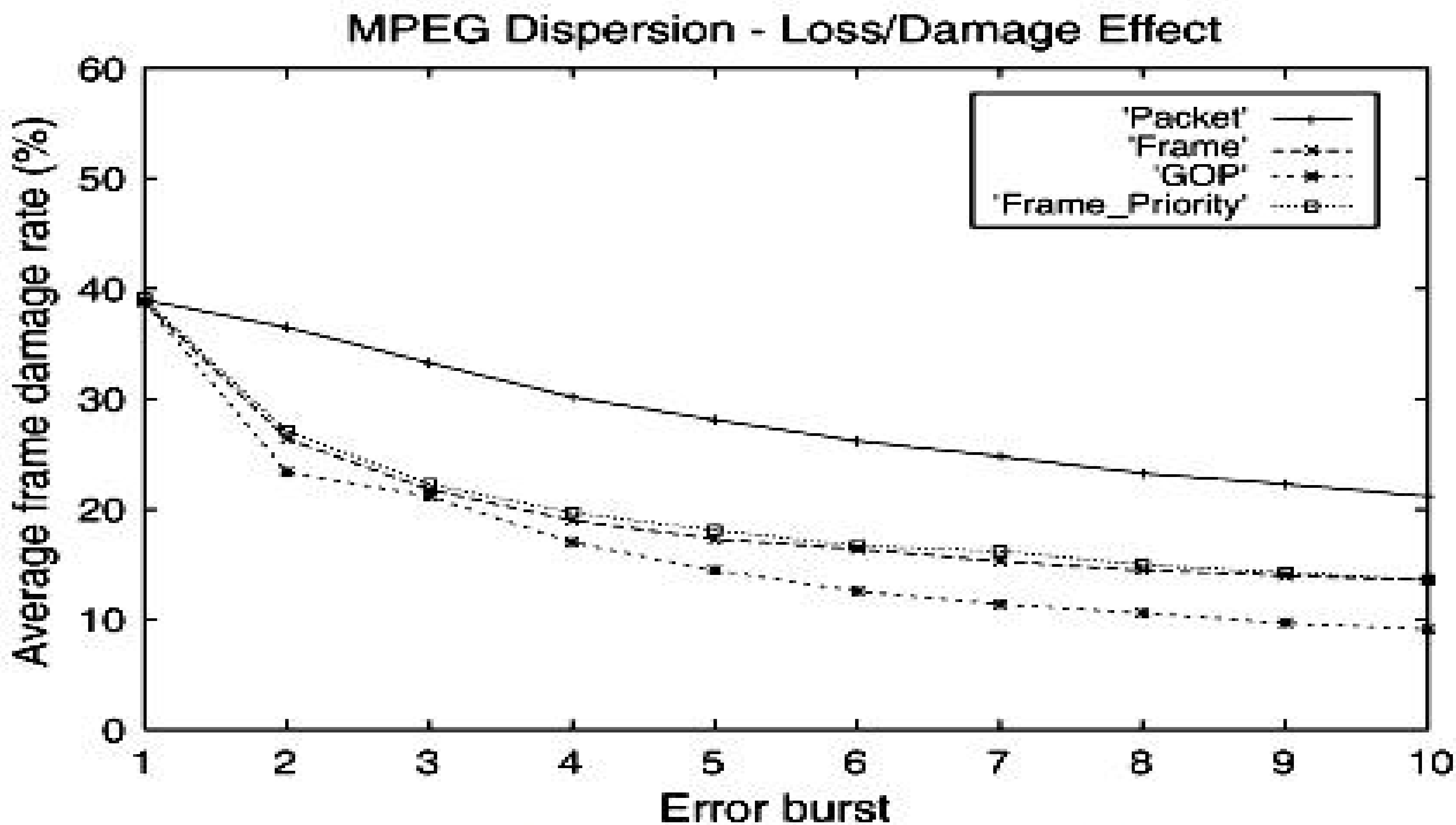

Fig. 11. Average frame damage rate, with Loss(0.03, 0.03, 0.03).

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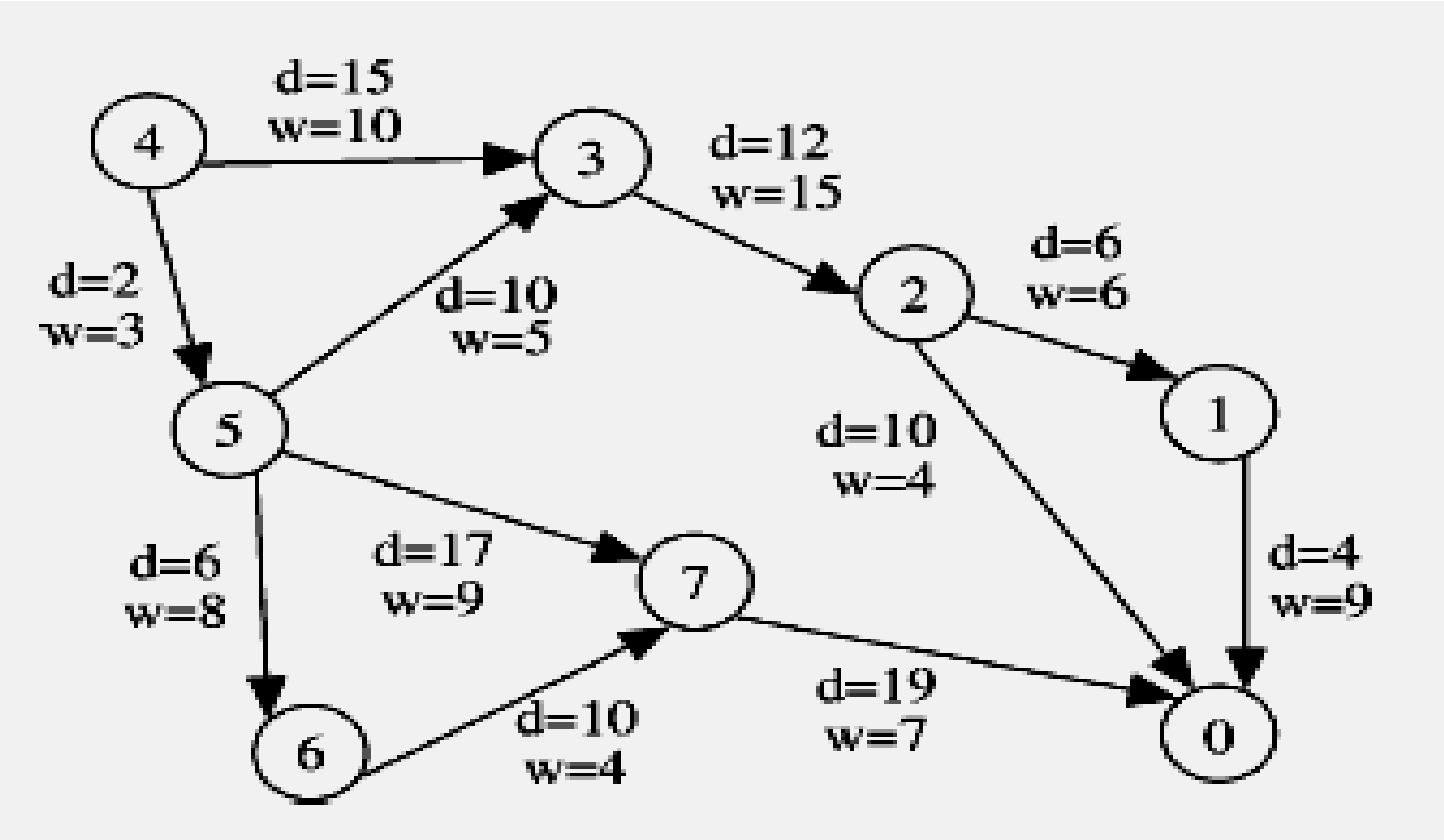
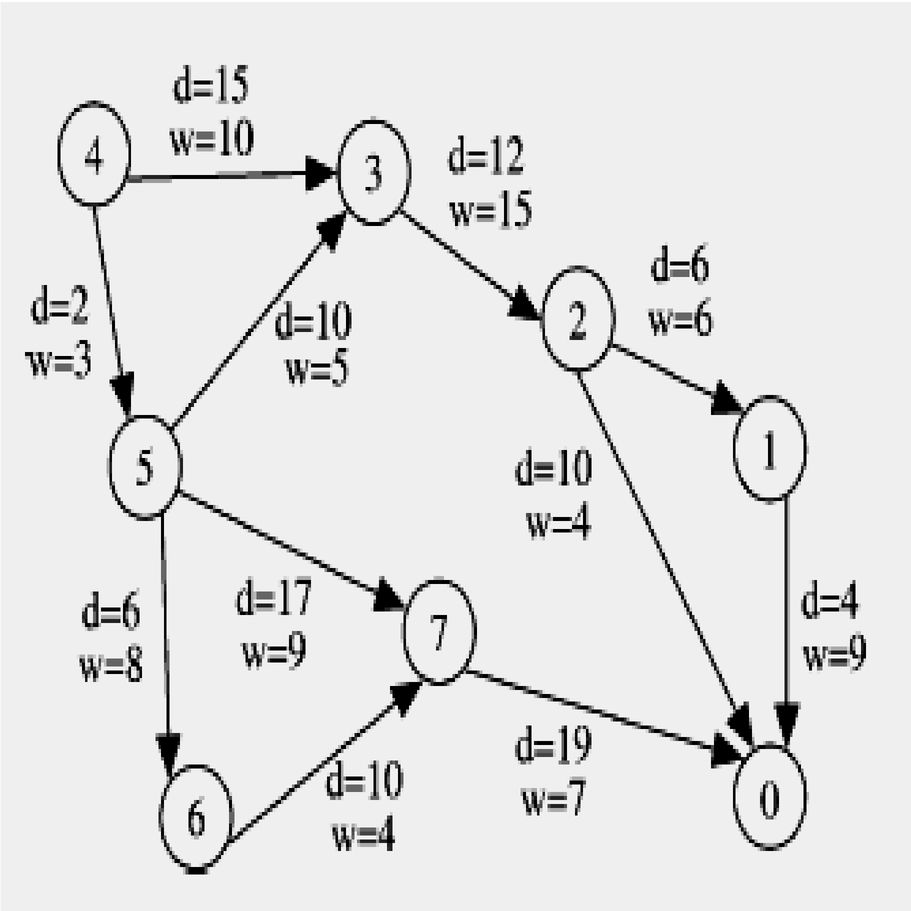
Altruistic Routing

- Why Altruistic Routing is Needed?
- Many proposed QoS routing algorithms consume resources more than necessary.
- An over-committing network resource increases the possibility of blocking future requests.
- ALTRA

A sample Network
d: Delay; w: Bandwidth



A Sample Network

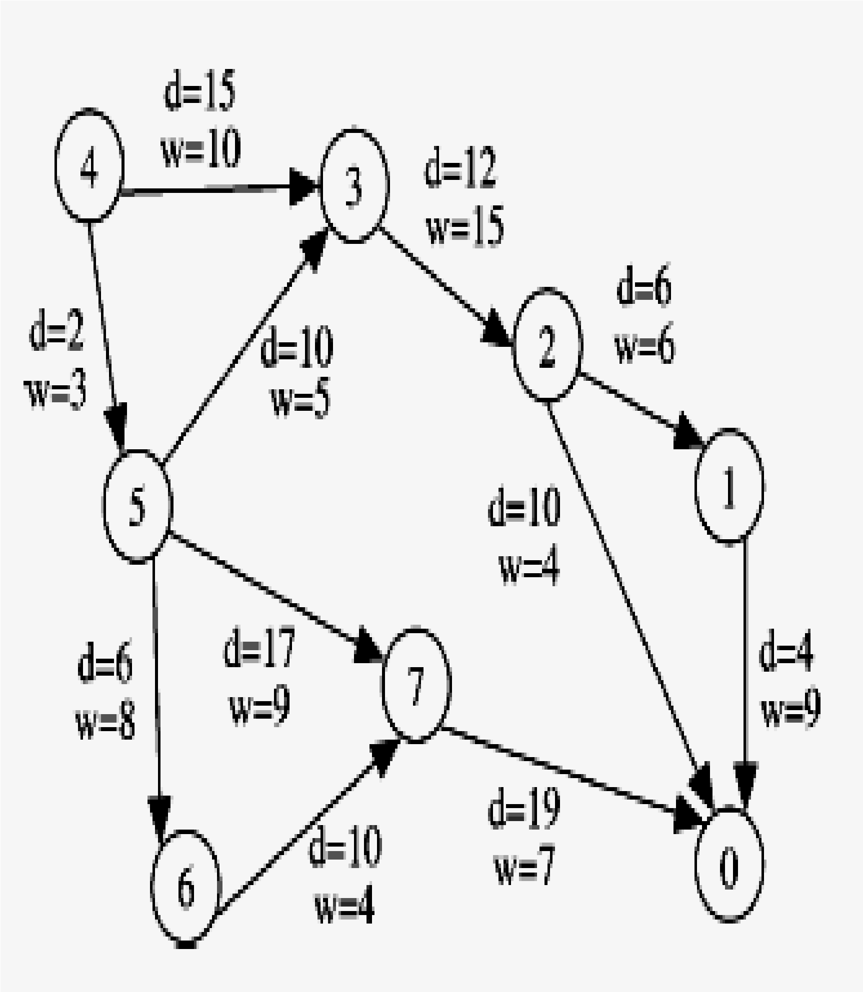


Paths	d	w
4->3->2->0	37	4
4->3->2->1->0	37	6
4->5->3->2->0	34	3
4->5->3->2->1->0	34	3
4->5->6->7->0	37	3
4->5->7->0	38	3

Key terms

- Dijkstras Algorithm
- Shortest-Widest Algorithm
- Widest-Shortest Algorithm
- Delay-favored algorithm
- Bandwidth-favored algorithm

A Sample Network



- R(D=37; W=4)
- Delay <=37
- Bandwidth >= 4
- Paths retrieved by Dijkstra's Algorithm by

Paths	d	w
4->5->3->2->0	34	3
4->5->3->2->1->0	34	3

Drawback of 1-metric routing algorithms

- The conventional algorithm, such as, Dijkstra's Algorithm serve their purposes well if the application requires only one metric to be met.

- But, most multimedia applications need to be satisfied with multiple-constraints.

2-metric routing example with unbalanced commitment of resources

- Request R1(D=40, W=2)
- Followed by the Request R2(D=34, W=3)
- Widest-Shortest delay Algorithm would assign following paths to R1

Paths	d	w
4->5->3->2->0	34	3
4->5->3->2->1->0	34	3

Parameters left for R2(D=34, W=3)

Paths	d	w	
4->3->2->0	37	4	: d>D
4->3->2->1->0	37	6	: d>D
4->5->3->2->0	34	1	: w<W
4->5->3->2->1->0	34	1	: w<W
4->5->6->7->0	37	1	: w<W
4->5->7->0	38	1	: w<W

- Path computation for R2 would FAIL.

Solution: Altruistic Routing

- A strategy that selects a routing path which is acceptable, if not necessarily the best, with respect to the users QoS's requirements.

- <u>Advantages</u>
  - Network utilization is increased.
  - Load is more evenly balanced.
  - Congestion becomes less likely

ALTRA-2 algorithm

$\mathcal{P}_0 \leftarrow$ find_all_qualified_paths( )

while ($|\mathcal{P}_0| > 0$) {

    if (in_favor_of_delay)

      $p \leftarrow$ narrowest_shortest($\mathcal{P}_0$)

    else if (in_favor_of_bandwidth)

      $p \leftarrow$ shortest_narrowest($\mathcal{P}_0$)

    $l \leftarrow$ critical_link(p)

$\mathcal{P}_1 \leftarrow \mathcal{P}_0$

$\mathcal{P}_0 \leftarrow \forall p_i \in \mathcal{P}_0$ and $l \notin p_i$

}

output $\mathcal{P}_1$

ALTRA-2 algorithm

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5   else if (in_favor_of_bandwidth)
6      $p \leftarrow$ shortest_narrowest($\mathcal{P}_0$)
7    $l \leftarrow$ critical_link(p)
8 $\mathcal{P}_1 \leftarrow \mathcal{P}_0$
9 $\mathcal{P}_0 \leftarrow \forall p_i \in \mathcal{P}_0$ and $l \notin p_i$
10 }
11 output $\mathcal{P}_1$

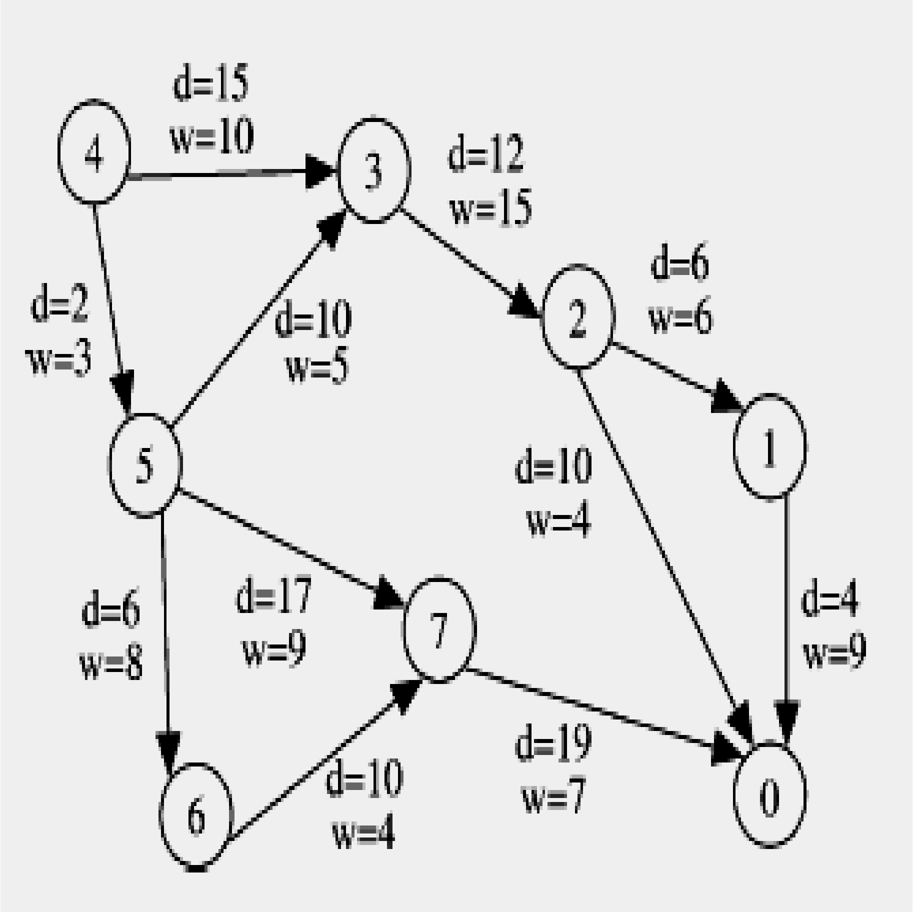
// In line 4, for delay-favored algorithm, Path# 3 would be chosen

// In line 7, critical_link is found to be link (4,5)

// In line 8, path set is saved

// In line 9,paths are removed containing critical_link

A Sample Network



Paths	d	w
4->3->2->0	37	4
4->3->2->1->0	37	6
4->5->3->2->0	34	3
4->5->3->2->1->0	34	3
4->5->6->7->0	37	3
4->5->7->0	38	3

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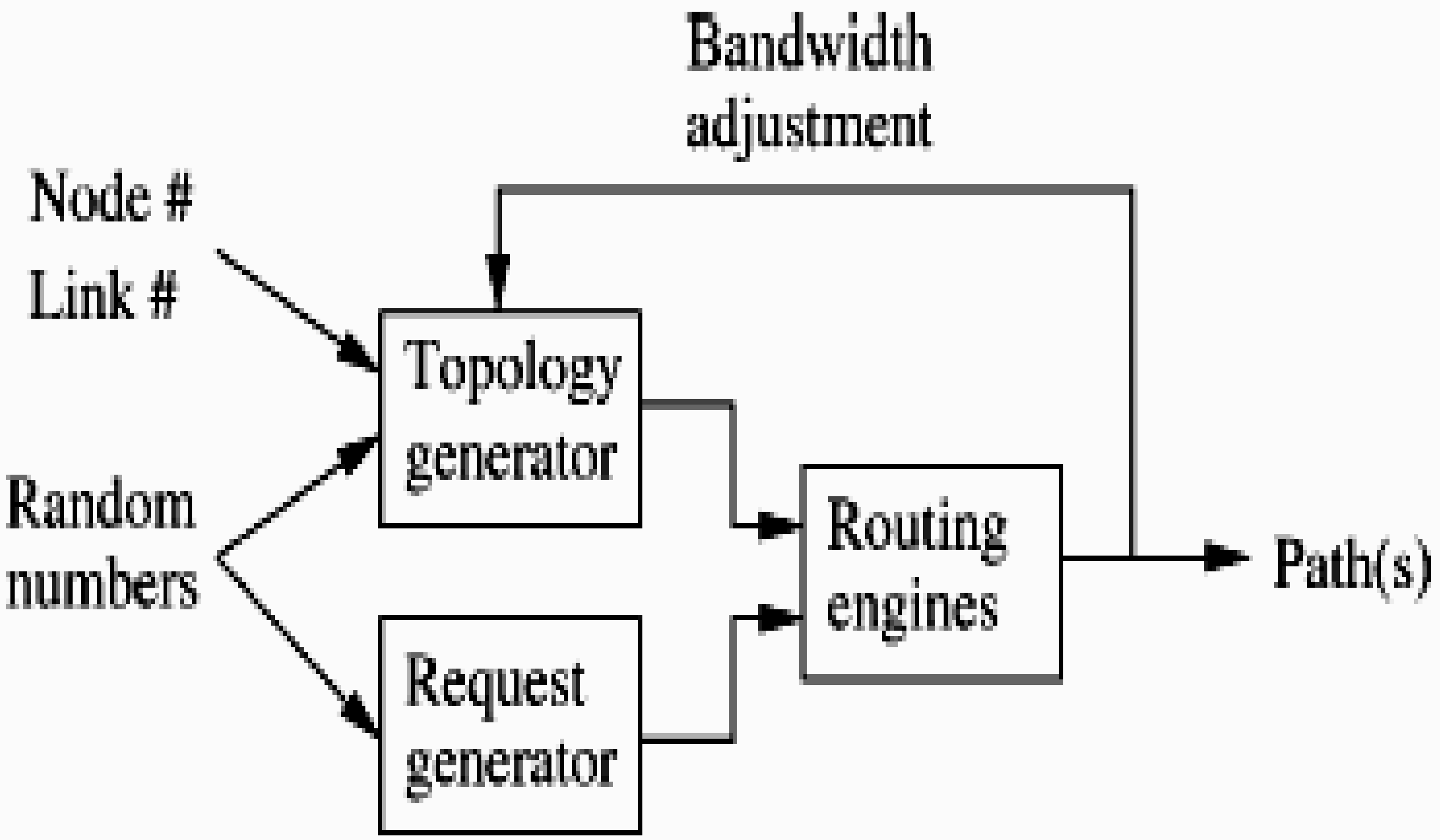
Result by ALTRA-2

Run	P_0 after step 2	p	l	P_1
1	{1,2,3,4,5}	3	(4,5)	{1,2,3,4,5}
2	{1,2}	1	(2,0)	{1,2}
3	{2}	2	(2,1)	{2}

Simulation Model



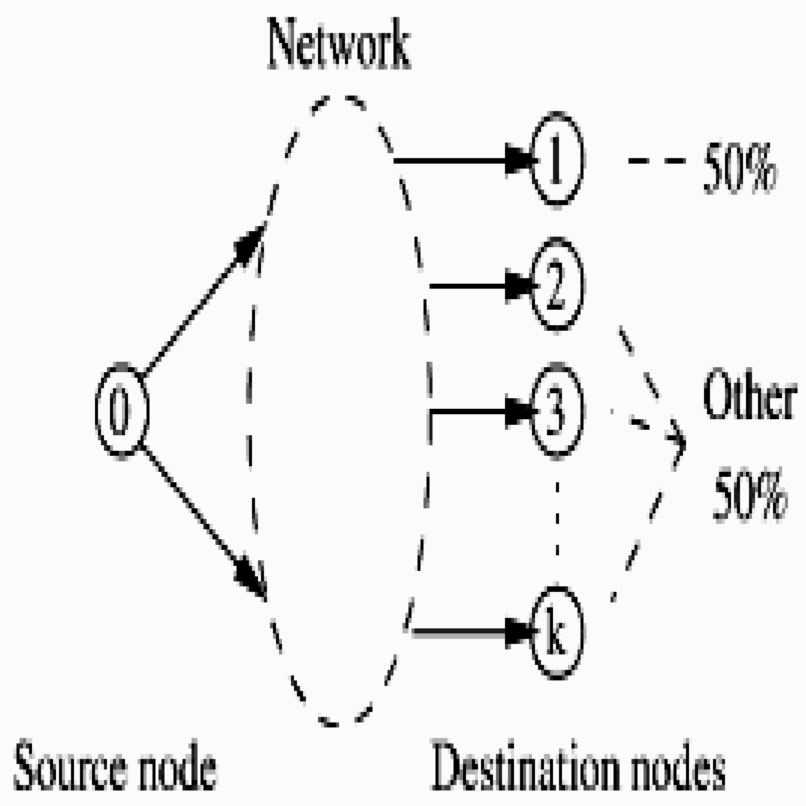
Simulation Model

- 1. Topology generator -> Include parameters N(nodes), L(links), and a random number seed. Network topologies are randomly generated.
- 2. Request Generator -> Carries request requirements; Maximum delay, minimum bandwidth & maximum loss rate.
- 3. Routing Engine -> Searches a path on the network topology. Connection denial if no path is qualified.

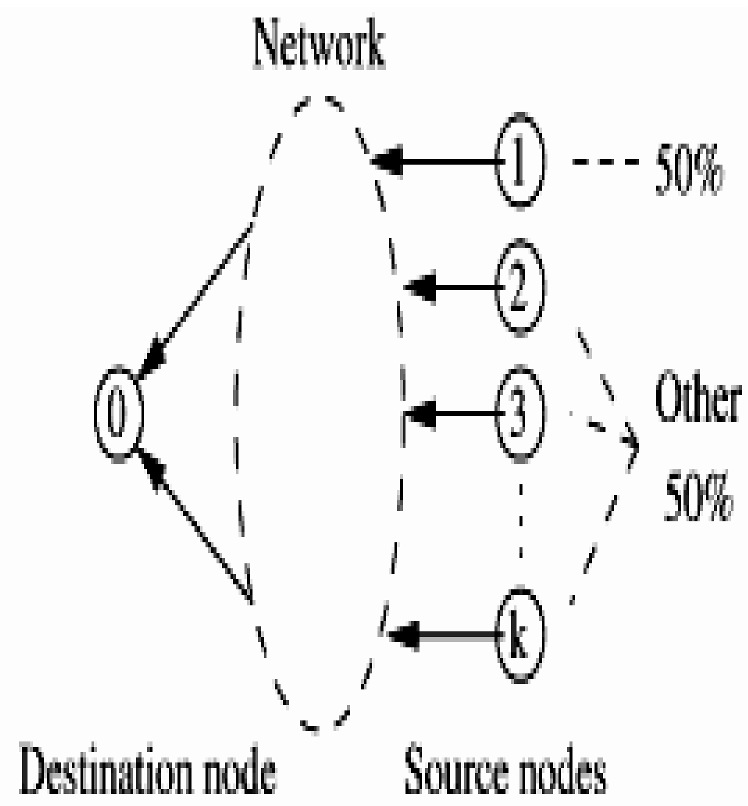
Simulation Results

- The concepts of hot spots represents the popularity of servers.
- In this simulation, a parameter is assigned to a node to represent its popularity.
- The definition of hot spot can be symmetric.
- In this simulation, source or destination based hot spots will exhibit similar behavior.

Examples of 50% hot spots



(a) An example of destination-based hot spot

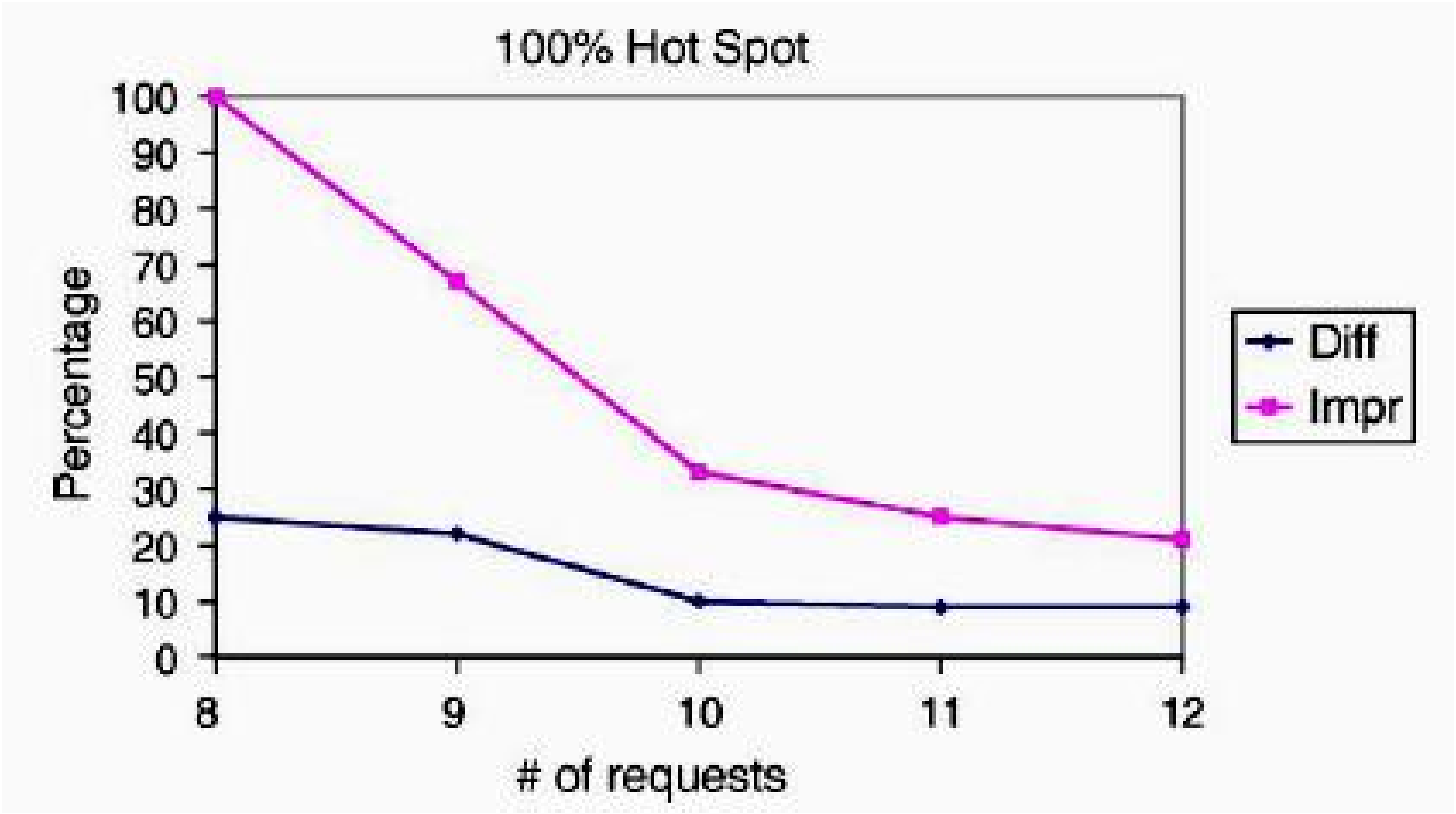


(b) An example of source-based hot spot

Simulation Results

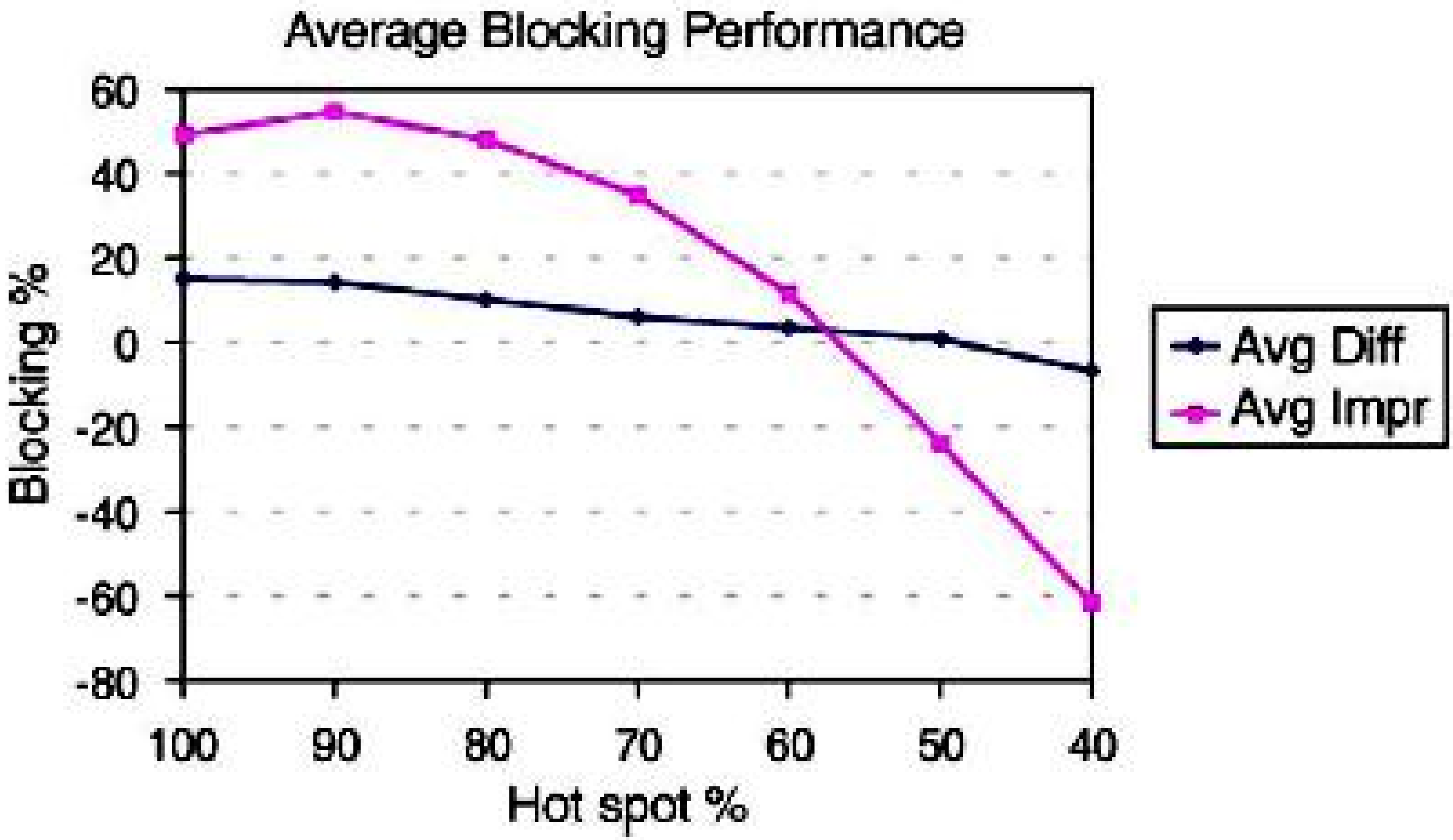
- The performance measurement for this simulation model is Average Request blocking Ratio.
- Improvement of ALTRA-2 algorithm compared to Widest-shortest delay algorithm.
- i.e. Compare BR*altra-2* and BR*wsd*.

Simulation Results



Blocking effect on 100% hot spot.

Simulation Results



Blocking effect with various hot spot percentages.

ALTRA-k algorithm

ALTRA-k algorithm

---

input k metrics $(m_1,\ldots,m_k)$
$\mathcal{P}_0 \leftarrow$ find_all_qualified_paths( )
while $(|\mathcal{P}_0| > 0)$ {
  $p \leftarrow \mathcal{F}_{m_k}(\mathcal{F}_{m_{k-1}}(\cdots(\mathcal{F}_{m_1}(\mathcal{P}_0))\cdots)$
  $l \leftarrow$ critical_link(p)
  $\mathcal{P}_1 \leftarrow \mathcal{P}_0$
$\mathcal{P}_0 \leftarrow \forall p_i \in \mathcal{P}_0$ and $l \notin p_i$
}
output $\mathcal{P}_1$

$\mathcal{F}_{\text{delay}} = \text{shortest}(\cdots)$, $\mathcal{F}_{\text{bandwidth}} = \text{narrowest}(\cdots)$, $\mathcal{F}_{\text{relaiability}} = \text{most\_re-leiabe}(\cdots)$.

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ALTRA – based Video Streaming

- Authors investigate the performance obtained by applying ALTRA routing to the proposed dispersion models.

- Frame type Based Dispersion
  - Authors simplify the priority-based strategy by limiting the frame priority assignment to only three levels: one for I-frames, one for P-frames, and one for B-frames. Hence, frame-type based model.

ALTRA – based Video Streaming(2)

- This dispersion strategy introduces the following impacts on QoS requirements:
- Bandwidth
  - The bandwidth requirement can be decomposed into three smaller requirements.
  - The relative bandwidth requirement for three sub-streams is:

$$R_{\mathrm{I}} : R_{\mathrm{P}} : R_{\mathrm{B}} = S_{\mathrm{I}} : \frac{S_{\mathrm{P}}(N-M)}{M} : \frac{S_{\mathrm{B}} N(M-1)}{M}$$

ALTRA – based Video Streaming(3)

- Reliability
  - I-frames can be decoded independently.
  - P-frames needs the previous I-frames, and B-frames need previous and future I- and P-frames for decoding.
  - Thus, high-quality delivery of the I-frames can prevent a cascading damage effect on the P- and B-frames.

ALTRA – based Video Streaming(4)

- System should select a channel with higher reliability for I-sub-streams

- System can choose a less reliable channel for B-sub-streams.

ALTRA – based Video Streaming(5)

- Delay
  - Timely and Synchronized arrival of I, P and B frames is important for the displaying an MPEG video
  - Dispersion based on frame types generates paths which have strong inter-path delay dependencies.
  - Authors illustrate that all the corresponding QoS Requirements are fulfilled.

Performance Blocking Ratio Improvement

- Blocking Ratio =

  (failed requests) / (total requests that arrive)

Characteristics of Simulation System:

1. n disjoint data channels; m arriving requests at a given time
2. (d_i = 1<=i<=n) & (D_i = 1<=i<=m) are distributed among n.

$\min(D_i) >= \min(d_i)$ & $0 < d_{(i+1)} - d_i <= T_{frame}$

Performance Blocking Ratio Improvement

3. Each data channel has (R_i+R_p+R_b) – unit bandwidth capacity and is randomly assigned a reliability level, either r1, r2, r3.

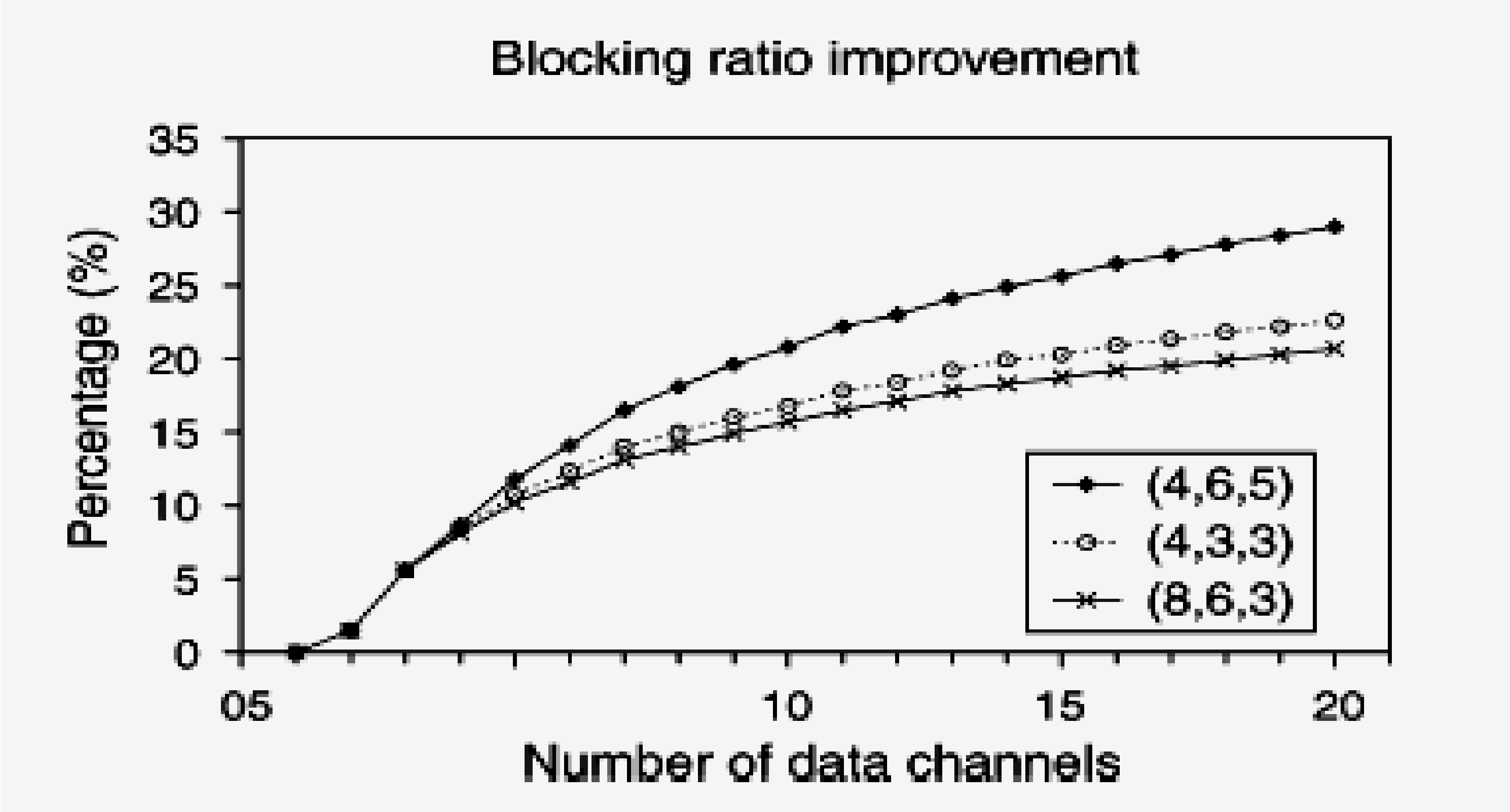
- Now set m=n ; without altruistic routing concept, make a baseline.
- Analyze the performance of three systems

Performance Blocking Ratio Improvement

MPEG dispersion bandwidth ratio

MPEG (N,M)	GOP	Dispersion (R_I, R_P, R_B)
(15,3)	IBBPBBPBBPBBPBB	(4,6,5)
(9,3)	IBBPBBPBB	(4,3,3)
(6,2)	IBPBPB	(8,6,3)

Performance Blocking Ratio Improvement



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Conclusion

- The performance of various MPEG models have been compared model by model.
- GOP and priority based models are the best.
- GOP based approach outperforms the priority-based approach when the variation of network link loss rate is small.

Conclusion

- When small links demonstrate, priority based models outperforms.
- ALTRA algorithms were proposed to effectively implement the altruistic routing.
- The analysis provides guidelines for designing live-video streaming and routing system when traffic dispersion is employed

Positives And Negatives

- Positives
  - Author's approach doesn't require new video compression algorithms or additional bandwidth.
  - Author's proposed dispersion strategies choose paths on network metrics, so sharing of links and nodes does not matter
- Negatives
  - Approach assumes presence of Diff- Serve aware MPLS networks
  - The relative priority within P frames is not considered in the final analysis.

Thank You

Your Questions