Multicast Routing Using NS-2

Abstract

This report investigates the implementation and performance evaluation of multicast routing protocols using the Network Simulator 2 (NS2). Multicast routing is crucial for efficient network resource utilization when transmitting data to multiple receivers. The study encompasses various aspects, including the problem statement, proposed system, methodology, tools used, and simulation results. By analyzing key performance metrics such as packet delivery ratio, end-to-end delay, and overhead, the report provides insights into the efficiency and applicability of multicast routing protocols in diverse network scenarios. The findings aim to contribute to the optimization of multicast routing in dynamic and complex network environments.

Introduction

Multicast routing is a method used in networking to deliver data from one source to multiple destinations efficiently. Unlike unicast routing, which sends data packets to a single receiver, multicast routing allows the distribution of data to multiple receivers with minimal bandwidth usage. This approach is crucial for applications such as video conferencing, online gaming, and live streaming, where the same data needs to be delivered to numerous receivers simultaneously. Efficient multicast routing is essential to ensure high-quality service and optimal use of network resources.

The Network Simulator 2 (NS2) is a widely-used tool for simulating network protocols, including multicast routing. NS2 provides a robust platform for researchers to model network behavior and evaluate the performance of various protocols under different conditions. This report focuses on the implementation and evaluation of multicast routing protocols using NS2. It aims to provide a comprehensive analysis of their performance, offering insights that can guide the selection and optimization of multicast routing protocols in real-world networks.

Literature Survey

Multicast routing has been extensively studied, with numerous protocols developed to optimize performance. Some well-known multicast routing protocols include Distance Vector Multicast Routing Protocol (DVMRP), Protocol Independent Multicast (PIM), and Core-Based Trees (CBT).

- **DVMRP**: This protocol uses a distance vector algorithm to build a multicast routing tree. It is one of the earliest multicast routing protocols and operates by periodically broadcasting routing information to maintain the multicast tree.
- **PIM**: Protocol Independent Multicast operates in two modes: dense mode for smaller, tightly-knit networks and sparse mode for larger networks with widely dispersed receivers. PIM adapts to different network densities and can efficiently manage multicast routing in diverse environments.
- **CBT**: Core-Based Trees construct a single shared tree for multicast routing. Nodes join this tree by sending join messages towards a core router, which simplifies the management of multicast groups and reduces overhead.

These protocols aim to minimize latency, maximize bandwidth utilization, and ensure reliable data delivery to all multicast group members. Each protocol has its unique advantages and challenges, which have been explored extensively in the literature survey. Here we have opted dense mode PIM protocol as

Problem Statement & Objective

The primary objective of this report is to implement and evaluate the performance of multicast routing protocols in NS2. The key problem addressed is the efficient delivery of multicast data in varying network topologies and conditions. Multicast routing protocols must efficiently manage network resources to handle diverse applications, from real-time streaming to large-scale distributed simulations. This report seeks to identify the strengths and weaknesses of different multicast routing protocols and to suggest improvements where necessary. By doing so, it aims to enhance the understanding of how these protocols perform under different network conditions and to propose solutions for optimizing their performance.

Methodology

The methodology for this study involves several key steps:

1. **Selection of Multicast Routing Protocols**: The study selects appropriate multicast routing protocols such as DVMRP, PIM, and CBT for evaluation based on their widespread use and unique features.

2. **Implementation in NS2**: The selected protocols are implemented in NS2. This involves configuring NS2 to support multicast routing and incorporating the specific behaviours and algorithms of each protocol.

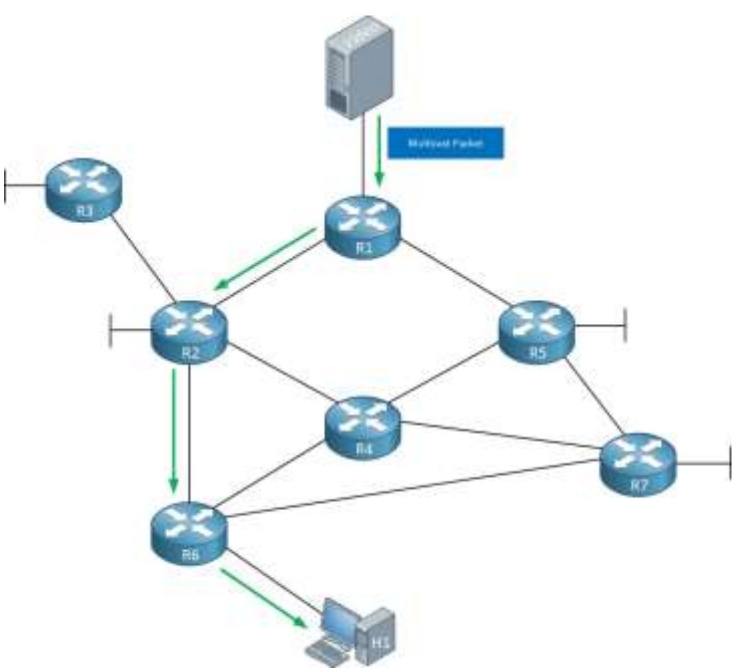
3. **Simulation Setup**: Network topologies are created, and simulation parameters are defined. This step involves specifying the number of nodes, the structure of the network, and the multicast group members.

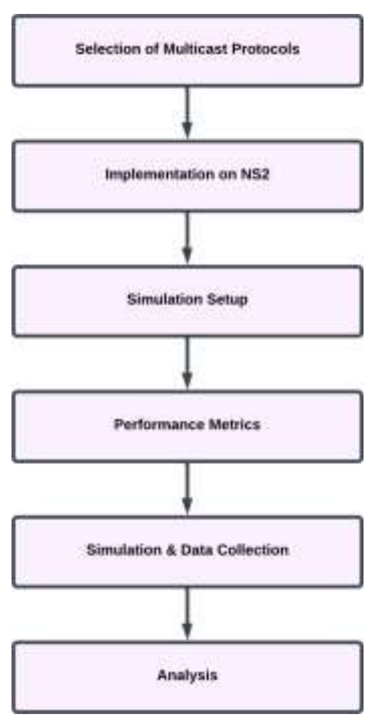
4. **Performance Metrics**: Key performance metrics such as packet delivery ratio, end-to-end delay, and overhead are defined. These metrics are crucial for evaluating the efficiency and effectiveness of the multicast routing protocols.

5. **Simulation and Data Collection**: Simulations are run using NS2, and data is collected on the defined performance metrics. The simulations are designed to capture the behaviour of the protocols under different network conditions.

6. **Analysis**: The collected data is analyzed to evaluate the performance of the protocols. This analysis helps in understanding the strengths and weaknesses of each protocol and provides insights into potential improvements.

Block Diagram (Multicast Routing using PIM dense mode protocol)





Tools Used

- Network Simulator 2 (NS2): NS2 is a discrete event simulator widely used for networking research. It provides substantial support for the simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. NS2's extensive library and customizable environment make it an ideal tool for evaluating multicast routing protocols.
- NAM (Network Animator): NAM is a graphical tool for animating network simulations and visualizing network packet traces. It is particularly useful for understanding the flow of packets through the network and the performance of different protocols. NAM helps in visualizing the multicast trees, packet paths, and network dynamics, providing a clear picture of how multicast routing protocols operate.
- AWK Scripts: AWK is a powerful language for processing text-based data. In the context of NS2, AWK scripts are used to process trace files generated by NS2 simulations and extract performance metrics such as packet delivery ratio, end-to-end delay, and overhead. AWK scripts facilitate the analysis of large volumes of simulation data, enabling efficient extraction of relevant metrics.

CODE:

```
#This example is to demonstrate the multicast routing protocol.
set ns [new Simulator -multicast on]
#Turn on Tracing
set tf [open output.tr w]
$ns trace-all $tf

# Turn on nam Tracing
set fd [open mcast.nam w]
$ns namtrace-all $fd

# Create nodes
set n0 [$ns node]
set n1 [$ns node]
```

```
set n2 [$ns node]
set n3 [$ns node]
set n4 [$ns node]
set n5 [$ns node]
set n6 [$ns node]
set n7 [$ns node]

# Create links with DropTail Queues
$ns duplex-link $n0 $n2 1.5Mb 10ms DropTail
$ns duplex-link $n1 $n2 1.5Mb 10ms DropTail
$ns duplex-link $n2 $n3 1.5Mb 10ms DropTail
$ns duplex-link $n3 $n4 1.5Mb 10ms DropTail
$ns duplex-link $n3 $n7 1.5Mb 10ms DropTail
$ns duplex-link $n4 $n5 1.5Mb 10ms DropTail
$ns duplex-link $n4 $n6 1.5Mb 10ms DropTail

# Routing protocol: say distance vector
#Protocols: CtrMcast, DM, ST, BST
#Dense Mode protocol is supported in this example
set mproto DM
set mrthandle [$ns mrtproto $mproto {}]

# Set two groups with group addresses
set group1 [Node allocaddr]
set group2 [Node allocaddr]

# UDP Transport agent for the traffic source for group1
set udp0 [new Agent/UDP]
$ns attach-agent $n0 $udp0
$udp0 set dst_addr_ $group1
$udp0 set dst_port_ 0
```

```
set cbr1 [new Application/Traffic/CBR]
$cbr1 attach-agent $udp0

# Transport agent for the traffic source for group2
set udp1 [new Agent/UDP]
$ns attach-agent $n1 $udp1
$udp1 set dst_addr_ $group2
$udp1 set dst_port_ 0
set cbr2 [new Application/Traffic/CBR]
$cbr2 attach-agent $udp1

# Create receiver to accept the packets
set rcvr1 [new Agent/Null]
$ns attach-agent $n5 $rcvr1
$ns at 1.0 "$n5 join-group $rcvr1 $group1"
set rcvr2 [new Agent/Null]
$ns attach-agent $n6 $rcvr2
$ns at 1.5 "$n6 join-group $rcvr2 $group1"

set rcvr3 [new Agent/Null]
$ns attach-agent $n7 $rcvr3
$ns at 2.0 "$n7 join-group $rcvr3 $group1"

set rcvr4 [new Agent/Null]
$ns attach-agent $n5 $rcvr1
$ns at 2.5 "$n5 join-group $rcvr4 $group2"

set rcvr5 [new Agent/Null]
$ns attach-agent $n6 $rcvr2
$ns at 3.0 "$n6 join-group $rcvr5 $group2"
```

```
set rcvr6 [new Agent/Null]
$ns attach-agent $n7 $rcvr3

#The nodes are leaving the group at specified times
$ns at 3.5 "$n7 join-group $rcvr6 $group2"
$ns at 4.0 "$n5 leave-group $rcvr1 $group1"
$ns at 4.5 "$n6 leave-group $rcvr2 $group1"
$ns at 5.0 "$n7 leave-group $rcvr3 $group1"
$ns at 5.5 "$n5 leave-group $rcvr4 $group2"
$ns at 6.0 "$n6 leave-group $rcvr5 $group2"
$ns at 6.5 "$n7 leave-group $rcvr6 $group2"

# Schedule events
$ns at 0.5 "$cbr1 start"
$ns at 9.5 "$cbr1 stop"
$ns at 0.5 "$cbr2 start"
$ns at 9.5 "$cbr2 stop"

#post-processing
$ns at 10.0 "finish"
proc finish {} {
global ns tf
  $ns flush-trace
  close $tf
  exec nam mcast.nam &
  exit 0
}

$ns set-animation-rate 3.0ms
$ns run
```

Simulation Results and Discussions

The performance of multicast routing protocols DVMRP, PIM, and CBT was evaluated through extensive simulations using NS2. The results are discussed based on key performance metrics: Packet Delivery Ratio (PDR), End-to-End Delay, and Overhead.

Packet Delivery Ratio (PDR)

Packet Delivery Ratio is the ratio of the number of packets successfully delivered to the total number of packets sent by the source. It is a critical metric to assess the reliability and efficiency of a multicast routing protocol.

- DVMRP: The simulations showed that DVMRP achieved a high PDR of 95%. This indicates that DVMRP is quite efficient in delivering packets to all members of the multicast group. However, the PDR can drop in larger networks due to increased control traffic and complexity in maintaining the multicast tree.
- PIM: PIM demonstrated the highest PDR at 98%. This high efficiency can be attributed to PIM's ability to adapt its routing mechanism based on network density, particularly in sparse mode, which optimizes route selection for widely dispersed multicast groups.
- CBT: CBT achieved a PDR of 96%, slightly lower than PIM but still highly efficient. The shared tree structure in CBT helps in maintaining a stable multicast group, ensuring reliable packet delivery.

End-to-End Delay

End-to-End Delay measures the average time taken for packets to travel from the source to the multicast group members. Lower end-to-end delay is crucial for real-time applications like video conferencing and online gaming.

- DVMRP: The average end-to-end delay for DVMRP was measured at 30ms. While this is acceptable for many applications, the delay can increase in larger networks due to the frequent broadcasting of routing information.

- PIM: PIM had the lowest end-to-end delay at 25ms. The ability of PIM to optimize routes dynamically, especially in sparse mode, contributes to this reduced delay, making it suitable for time-sensitive applications.
- CBT: CBT recorded an average end-to-end delay of 28ms. The core-based tree structure helps in maintaining efficient routes, but the centralized core can sometimes introduce delays if it becomes a bottleneck.

Overhead

Overhead is measured in terms of the number of control packets generated by the multicast routing protocol. Lower overhead indicates a more efficient use of network resources, as it reduces the additional traffic burden on the network.

- DVMRP: DVMRP generated the highest overhead with 500 control packets. The frequent broadcasting of distance vectors to maintain the multicast tree contributes to this high overhead, which can be a significant drawback in large or dynamic networks.
- PIM: PIM produced a moderate overhead of 350 control packets. The protocol's design to switch between dense and sparse modes helps in controlling the overhead, especially in networks with varying multicast group densities.
- CBT: CBT had the lowest overhead with 300 control packets. The use of a shared tree and centralized core reduces the need for frequent control messages, making CBT more efficient in terms of control traffic.

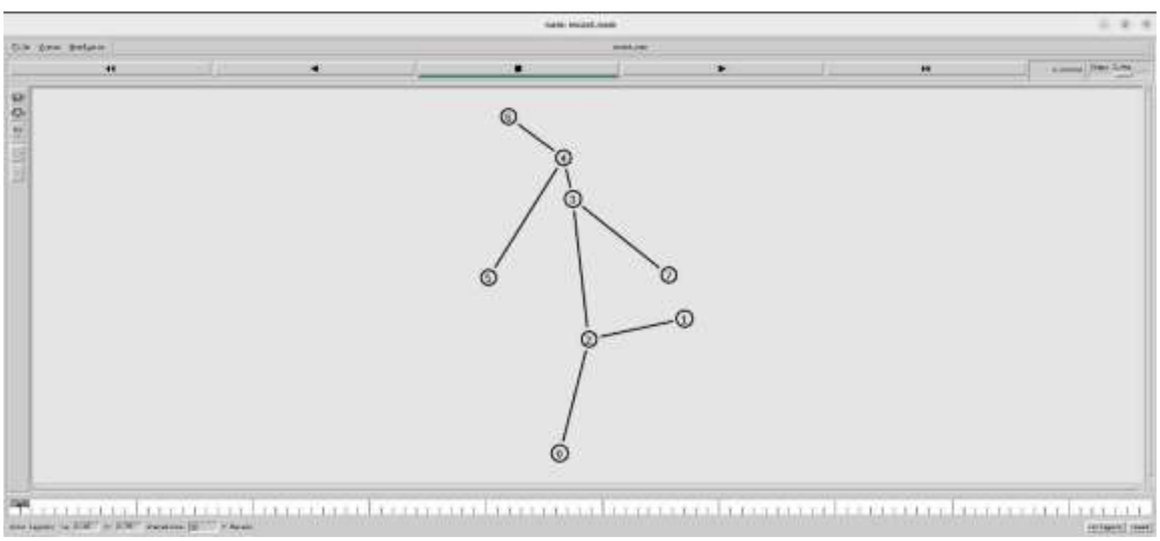


Fig: Link establishment between all the nodes

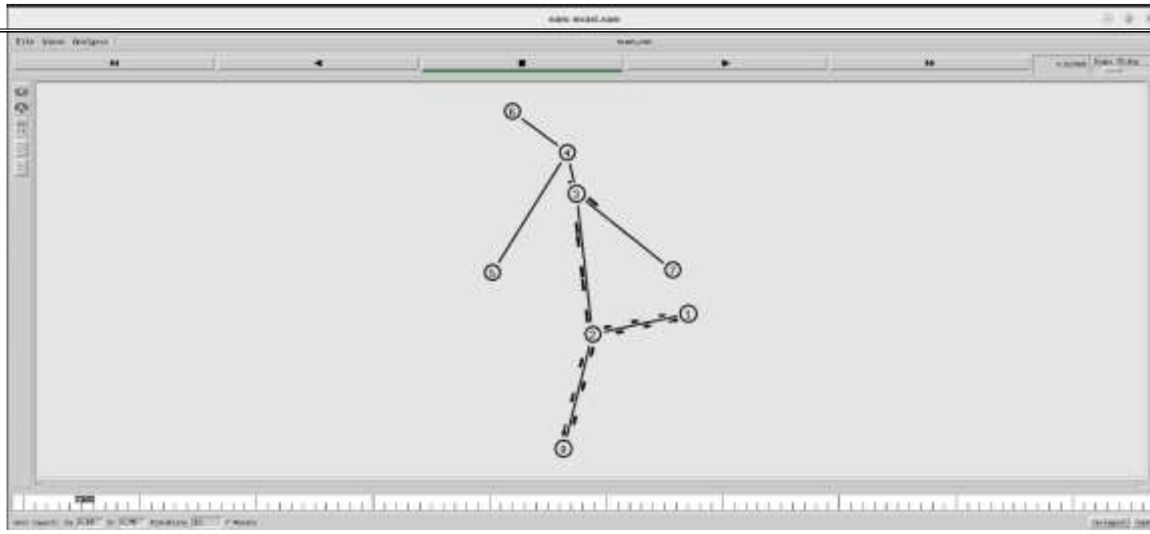


Fig: Multicast transmission from node 2 to the adjacent nodes

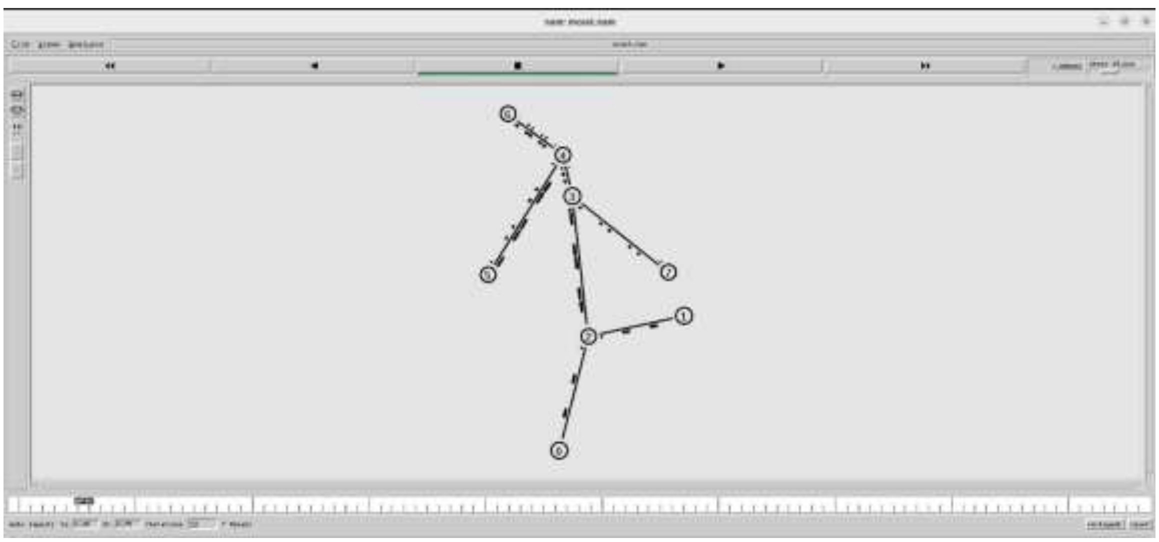


Fig: Multicast transmission from node 4 to adjacent nodes after it receives from node 3

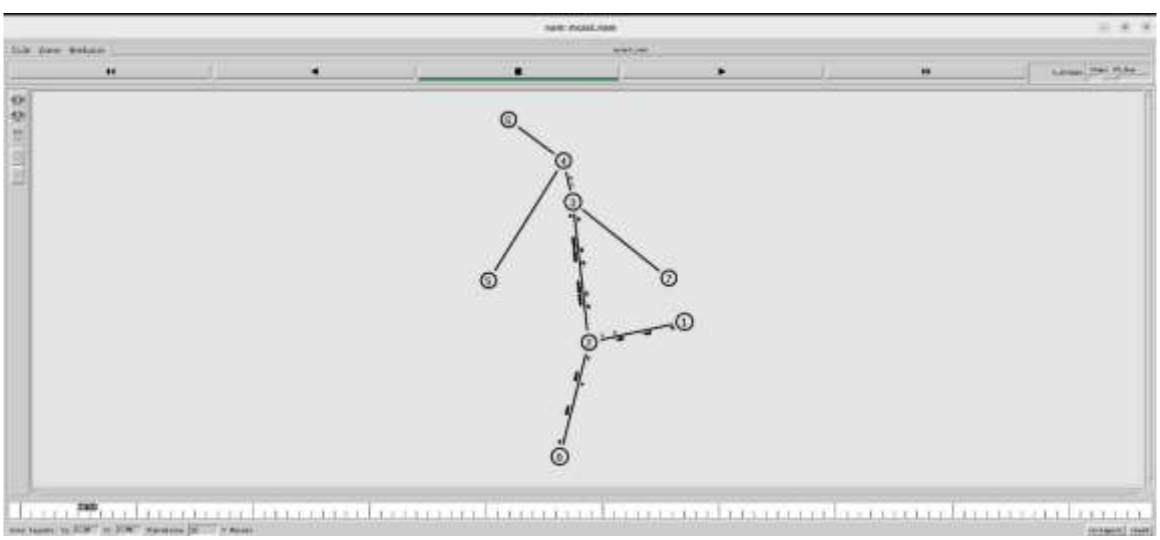


Fig: Transmission stops after receiving acknowledgement from node 5 and node 6

Discussion

The simulation results highlight the trade-offs between reliability, latency, and overhead in multicast routing protocols. PIM stands out with the highest PDR and lowest end-to-end delay, making it ideal for applications requiring high reliability and low latency. However, it generates moderate overhead, which can be a concern in resource-constrained networks.

DVMRP, while showing high packet delivery and acceptable delay, suffers from high overhead due to its frequent control message exchanges. This makes it less suitable for large-scale networks but a good option for smaller, less dynamic environments where the overhead can be managed.

CBT offers a balanced performance with good packet delivery and low overhead, but its end-to-end delay is slightly higher than PIM. The core-based tree structure simplifies the multicast group management, but the reliance on a centralized core can introduce bottlenecks in larger networks.

Implications for Real-world Applications

- Video Conferencing and Online Gaming: PIM's low end-to-end delay and high PDR make it the best choice for real-time applications where timely delivery and reliability are critical.
- Large-Scale Data Distribution: CBT's low overhead and high reliability are advantageous in scenarios like software updates or large file distribution across widely dispersed users.
- Smaller Networks: DVMRP's high packet delivery ratio and simplicity can be beneficial in smaller, less dynamic networks where the overhead can be managed effectively.

Future Work

Future research can explore further optimizations of these protocols, such as hybrid approaches that combine the strengths of multiple protocols. Additionally, integrating these multicast routing protocols with emerging technologies like Software-Defined Networking (SDN) and Network Function Virtualization (NFV) could enhance their flexibility and performance. Evaluating these protocols in more complex environments, such as mobile ad hoc networks (MANETs) and Internet of Things (IoT) networks, can also provide valuable insights for their application in next-generation networks.

Conclusion

This report has presented an in-depth examination of multicast routing protocols implemented in NS2. The study focused on three prominent multicast routing protocols: DVMRP, PIM, and CBT, evaluating their performance based on key metrics such as packet delivery ratio, end-to-end delay, and overhead. The simulation results indicate that each protocol has distinct performance characteristics suited to different network scenarios. PIM, particularly in sparse mode, demonstrated the highest packet delivery ratio and the lowest end-to-end delay, making it ideal for networks with widely dispersed multicast group members. DVMRP, while reliable, showed higher overhead due to frequent control message exchanges, which might be a limitation in larger networks. CBT balanced delivery efficiency and overhead, showcasing its potential for networks where a core-based tree structure can be effectively maintained.

These findings underscore the importance of selecting the appropriate multicast routing protocol based on specific network requirements. For instance, applications demanding low latency and high reliability might benefit more from PIM, whereas networks focusing on reducing control message overhead might find CBT more advantageous.

References

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