CSLR52
COMPUTER NETWORKS LAB

PROJECT REPORT

Group No. 17

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A Reliable Multicast Transport Protocol for Device Management in Space-ground Integrated Network

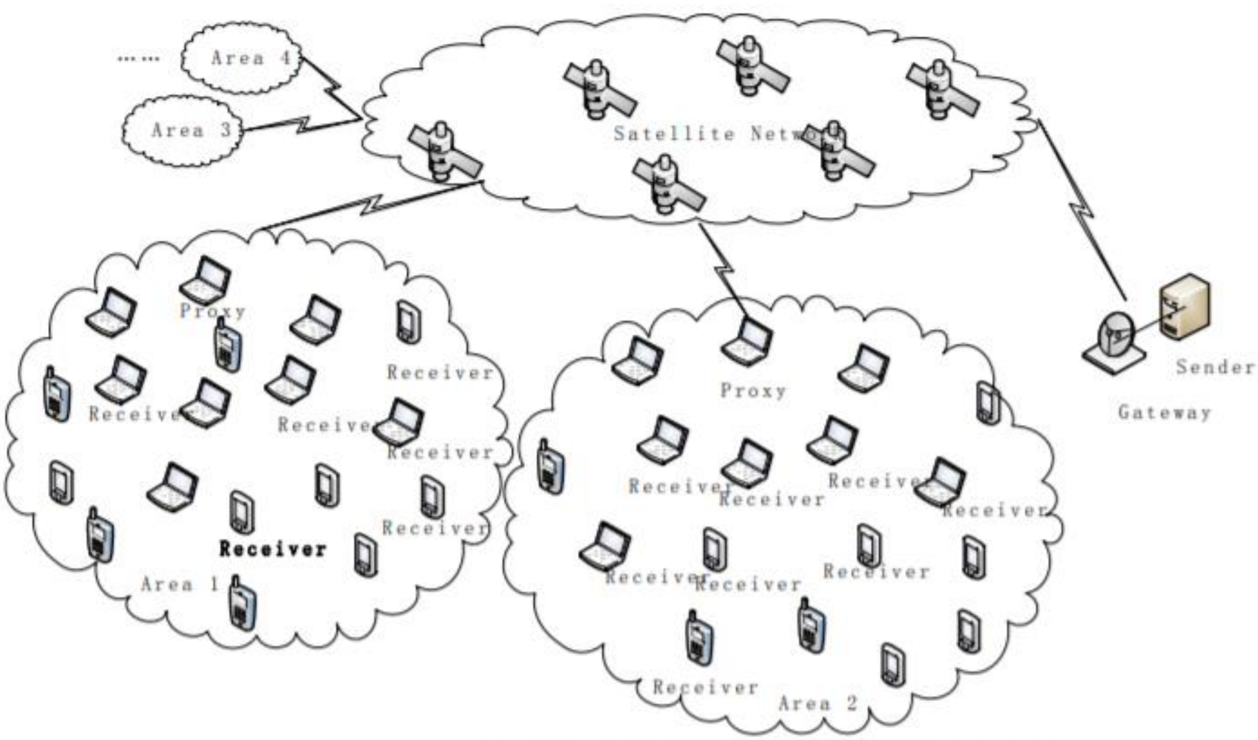
Abstract

In the space-ground integrated network, management centers usually need to send the same management information to different devices reliably. The multicast protocol is more suitable considering the characteristics of satellite networks in broadcast and limited resources for device management than the unicast protocol.

However, the existing reliable multicast transport protocols tend to maintain a stable structure during the entire lifecycle, which sharply reduces the efficiency and is not suitable for device management in satellite networks.

This paper suggests a design for a reliable multicast transport protocol for device management, which contains two key ideas:

- In the aspect of acknowledgment aggregation, we design a rapidly tree-organized scheme for a temporary structure in each transmission to reduce the time cost in a dynamic multicast group forming.
- Regarding local error recovery, we present an evaluation scheme in the quality of communication to choose a less-energy-cost way between local multicast and local broadcast to relay.



Satellite multicast scenario.

Introduction

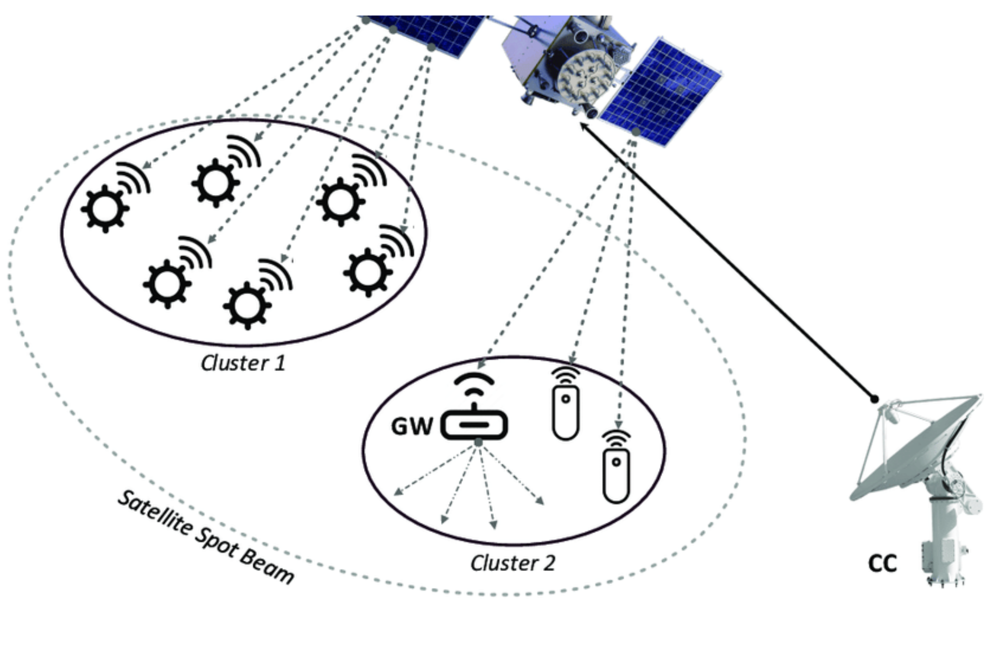
a. Why the problem is essential?

As a means to manage the devices, the control information plays a crucial role. That's why control information must be sent reliably. To deal with the same situation in various devices, the management message sent to different receivers keeps accord.

Multicast provides a more efficient way to transmit device management messages than unicast. Moreover, multicast through satellite networks large the global coverage and reduce the hops between sender and receivers.

While satellite networks have the characteristics of high bit-error rate and limited uploads bandwidth, which limits the quality of reliable transmission.

A reliable multicast protocol can be improved from feedback and
retransmission to suit the satellite network.



b. What is the problem & why it needs to be solved?

The control message of devices is short but important. Moreover, every message of management accords to a specific threat, such as the information aiming at the Android system's bugs is only passed to the users of the Android.

These characteristics distinguish control messages from data messages, e.g. video streams. Thus, the management message has the following additional problems.

1. The control message is sent to different users from time to time, and the multicast structures changes frequently.

2. Compared to the data message, which ups to MBs, and even GBs, the control message is much shorter.

3. The time spent on restructuring counts more than that spends on data transporting in the total time.

Solving these problems will make communication much reliable and faster.

c. Overview of the proposed approach.

Ideas suggested in the base paper

Fast-multicast tree building method:
We propose a method to cut the time used in tree structuring, which could fit the frequently changed destinations in device management and evenly save the time used in transmission.

Autonomous retransmission alternative scheme:
We propose a scheme to optimize the tree multicast, in properly choosing a way to retransmit messages between the multicast and broadcast. The scheme is based on the communication quality during this transmission and aims to reduce the overall energy consumption in a group.

***Modification*:**

We extended the above ideas to Vehicular Ad Hoc Networks (VANETs), by implementing the Hybrid Routing Protocol Using a Modified K-Means Clustering Algorithm.

d. Outline of the paper

A classic solution in multicast for satellites is to organize a logical hierarchical tree in local error recovery. The aim of these protocols is to maintain a stable structure. Via the tree structure, messages retransmit to all nodes, including the dynamic ones for error recovery.

While the device management messages may only need to be passed to some of the nodes, maintaining a stable structure for all nodes over time is quite inefficient. Hence, the stable structure loses its superiority, under the condition of destinations changing all the time, which is exactly the situation the device management protocol works for.

This paper presents a reliable multicast transport protocol for device management, to fix the problems met in the transmission. For the sake of the characteristics of the satellite network, acknowledgment aggregation and local error recovery are necessary for the protocol.

In the protocol, a rapidly forming prototyping structure for the multicast group in each message-spreading period is provided, which can be used in both local error recovery and acknowledgment aggregation. In local error recovery, an alternative scheme is provided, choosing from the tree structure and broadcast to retransmit the message.

2. Related Work

a. Related existing work

In TCP-Peach++: Enhancement of TCP-Peach+ for Satellite IP Networks with Asymmetrical Bandwidth and Persistent Fades (https://link.springer.com/chapter/10.1007/11569596_17), a logical hierarchical tree is created for local error recovery and acknowledgment aggregations to avoid message repeat and acknowledgment implosion in the low bandwidth link.

In **An agent-based reliable multicast transport protocol for satellite networks** **(** https://dl.acm.org/doi/10.1145/3220162.3220173) a negative ACK (NACK) scheme is used for feedbacks of the incorrectly received content, and a packet-level forward error correction (FEC) is used for local error recovery.
The proxy takes the responsibility for the feedback and local FEC in the group. These protocols give good solutions in a multicast for satellites. While their work costs a long time in waiting group numbers' acknowledgment and local error recovery before the proxy responds to the sender, which makes the message transmission inefficiently.
And the stable structure they hold is not suitable for device management.

In these,

Reliable multicast transport of BGP for geostationary satellite networks Communications
(https://ieeexplore.ieee.org/document/6364165)

NCSR: Multicast transport of BGP for geostationary Satellite network based on Network Coding
(https://ieeexplore.ieee.org/document/7119261)

Optimized short message transmission for reliable communications over satellite broadcast channels
(https://ieeexplore.ieee.org/document/6831519)

The method of network coding is presented to improve the recovery efficiency in multicast retransmission. Network coding is to mix different incorrectly delivered information together before retransmission. It is a valid way to relay messages in reducing the packet numbers in the link. While under the condition of receivers changing often, the scheme could not work in its best situation.

In **NTCP: Network-assisted TCP for long delay satellite network** https://ieeexplore.ieee.org/document/7586710,
a method of reliability guaranteed to publish/subscribe service is presented to deal with large-scale multicast.   The service works as a layered multicast, which could adjust autonomously and dynamically with the requirement of destination without.

b. Summary table

Methods	Time cost (sec)	Energy units cost (1 * 10 ^6)	Throughput (Mb/s)	Packet Loss (%)	End to end Delay (ms)
Classical multicast protocol TCP Peach++ (MT)	65	5	2.72	23	68
Broadcast protocol based on Network Coding (NC)	50	3	5.12	21	53
Our multicast protocol for device management (MDM)	40	4	6.23	15	47

c. How your work differs from these works?

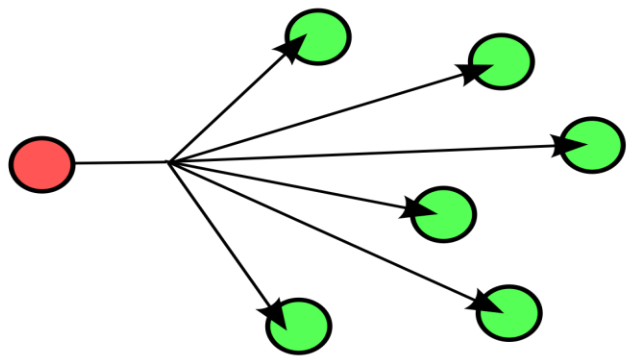
Some of the related protocols give good solutions in a multicast for satellite but their work costs a long time in waiting group numbers' acknowledgment and local error recovery before the proxy responds to the sender, which makes the message transmission inefficient. And the stable structure they hold is not suitable for device management.

Also, there are valid ways to relay messages in reducing the packet numbers in the link but under the condition of receivers changing often, those schemes could not work in their best condition.

The applicability of FEC is added in a few tree structures for reliability but the destination of the service stays in a stable state, which does not changes with the situation as that happens in device management.

d.Contribution

We also implemented a Broadcasting Network based on *Ad hoc On-Demand Distance Vector* Routing Protocol.
This can be used when Multicast Transport Protocol is not feasible with networking conditions as illustrated in the latter part of the Base Paper.



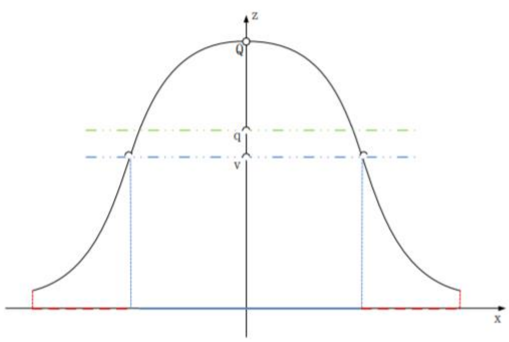


Figure 4. Relation between devices' distribution and communication's quality.

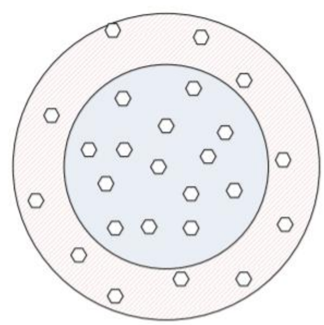


Figure 3. Location of devices in a group.

The number of the failed nodes is larger than 1/3 of the total devices in the group, and a broadcast relay is more effective for the group. Otherwise, that means the number of the failed nodes is less the 1/3 of them and relaying in multicast tree suits better in the group.

We extended the above ideas to Vehicular Ad Hoc Networks (VANETs), by implementing the Hybrid Routing Protocol Using a Modified K-Means Clustering Algorithm.

3. Proposed Work

a. Overall description of the proposed work

Ideas suggested in the base paper for the multicast transport protocol

- In the aspect of acknowledgment aggregation, we design a rapidly tree-organized scheme for a temporary structure in each transmission to reduce the time cost in a dynamic multicast group forming.
- Regarding local error recovery, we present an evaluation scheme in the quality of communication to choose a less-energy-cost way between local multicast and local broadcast to relay.

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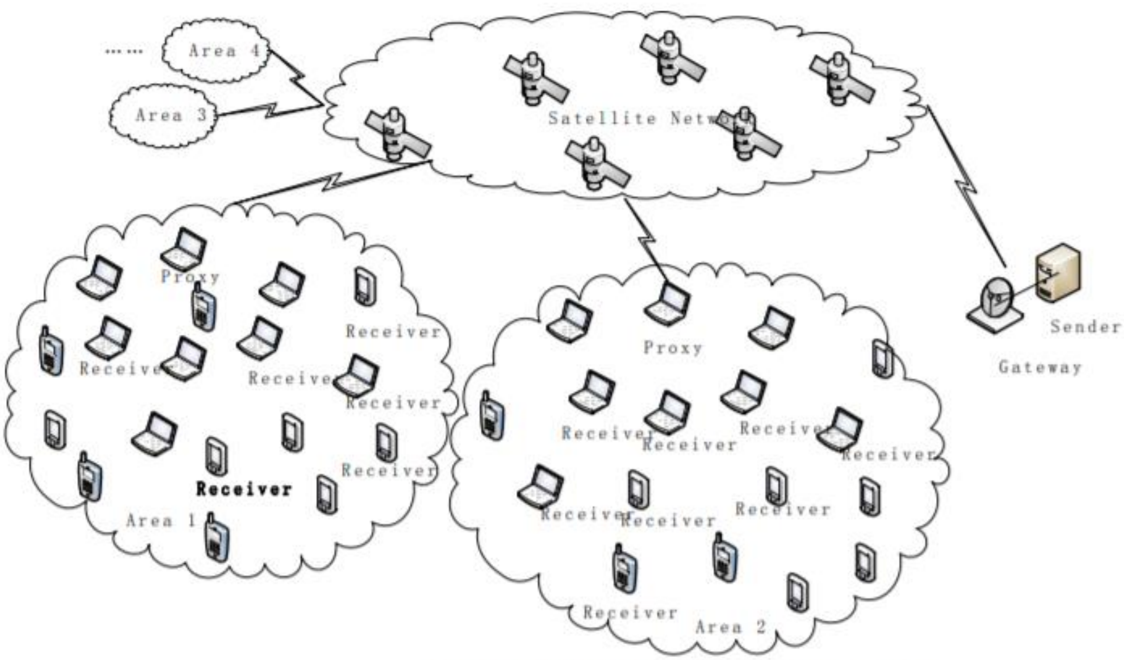
b.Detailed explanation of the proposed approach

THE MULTICAST PROTOCOL

Structure

In this, we consider the multicast-based scheme. The scenario is shown in



Satellite multicast scenario.

The sender holds all the receivers' knowledge about places, energies, network conditions, and so on. The receivers are in a huge number, dispersed in the planet. All of them could communicate to and from the satellite.

Some receivers may have terrestrial connections among them. Not all receivers necessarily need to be connected by terrestrial networks, but those who are in a certain scope and connected together by a terrestrial network are set into a group.
Before sending the message, a packet-level Forward Error Correction (FEC) with the error-correcting capability of *t* bits in the d-length is added.

The multicast protocol can be divided into two phases:

1. Sender connects with receivers via satellite link, which we called the geo-satellite phase.

2. Receivers organize error-recovery and feedback among a group, which we called the terrestrial phase.

The Geo-satellite Phase

The target of this phase is to transfer the control messages from the sender to the receivers. Instead of getting all the nodes a reliable transport protocol, the sender just promises only one node to hold the complete and correct message.

The special node is named a ***proxy***. The sender chooses the proxy among the group by the standard of comprehensive ability, which can be measured as follows:

$$F = k_1 * E + k_2 * B + k_3 * D + \frac{k_4}{M}$$

Where F is comprehensive ability, E is energy, B is link bandwidth, D is node degree, M is node mobility, and k1 to k4 is adjusted coefficient, which can be adjusted according to the actual situation.

The knowledge of receivers mentioned above is known by the sender before making the control message. Before a reliable unicast is sent to the proxy, the management centers send a broadcast via satellite to the area.
All nodes in the area could hear the message, but the message may be wrong, due to the high bit error rate of the satellite link.

All the nodes could tell themselves from the destination field in the message header. If the node gets itself not in the file, it drops off the packet. Otherwise, the nodes keep the message ID and data for the next phase. In some rare situations, mistakes may occur in the destination field.
At the end of this phase, the proxy would hold the full and correct message, while the others may have the same copy.

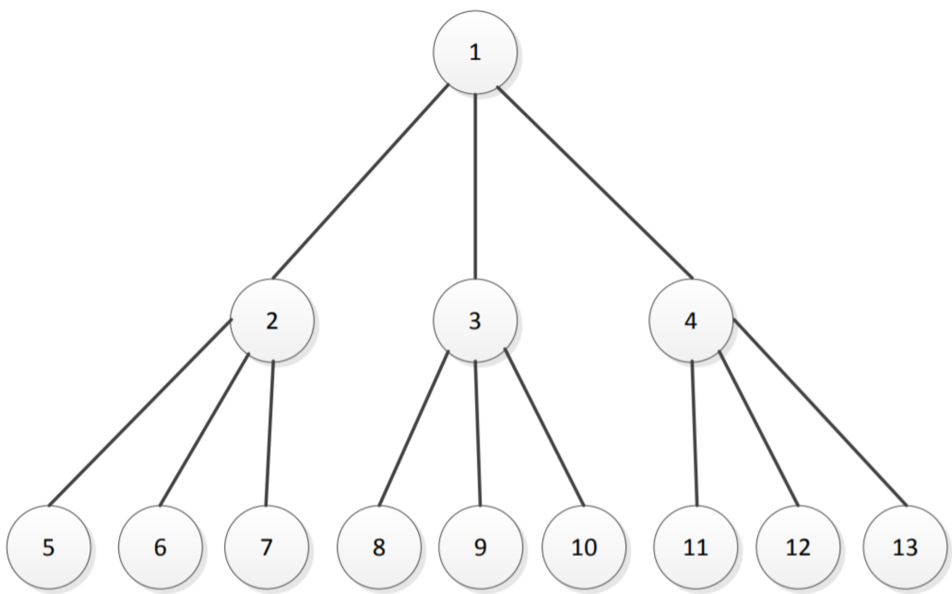
The Terrestrial Phase

The target of this phase is to set all receivers in a group to get the messages completely and correctly. The phase can also be divided into two parts. One part works on local error recovery, the other works on acknowledgment aggregation.

In local error recovery, the proxy retransmits the correct data to the needed nodes. After receiving the correct message, in acknowledge aggregation, normal nodes in the group feedback to the proxy, and the proxy feedbacks to the sender, which means the end of the transmission.

The multicast tree structure is suitable for the feedback transport for all the nodes that need to transmit data to the proxy. However, in the error recovery, only a part of the nodes need the duplicate from the proxy. And the number is affected by the quality of satellite communication.

Therefore, we propose a scheme to evaluate the quality of communication, and choose a less-energy-cost way between local multicast and local broadcast.



Multicast tree in K=3 scenario.

The Fast-multicast Tree Building Method

The tree is organized quickly by the clue of the destination file in the packet, which can be seen as a hierarchy traversal sequence of a tree with out-degree K.

The number of K is adopted by the sender, in considering the number and the distribution of nodes in a group. The destination file keeps all nodes in a group in the order of the comprehensive ability, which is counted. From the field, a node gets the

knowledge of its parent node and children nodes, where it sends the feedback to and gets the feedback from.
For every node in the field that holds the clue, a logical multicast tree arises.

Modification

We also implemented a Broadcasting Network based on *Ad hoc On-Demand Distance Vector* Routing Protocol.

Vehicular Ad Hoc Networks (VANETs), implemented by the Hybrid Routing Protocol Using a Modified K-Means Clustering Algorithm.

Algorithm 1 - Pseudo Code of K-Means

Input: Number of centroids k; Set of points N; List of centroids randomly assigned C_k.
Output: Set of clusters with their centroids.
Begin
1: **Repeat**
2: **For** each data point in N **do**
3: Calculate the distance between the data point and the centroid of each cluster using equation (1).
4: Assign the data point to the nearest centroid.
5: **End for**
6: **For** each cluster in C_k **do**
7: Calculate the new centroid position using equation (2).
8: **End for**
9: **Until** All data points belong to a cluster or the maximum number of iterations is reached.
End

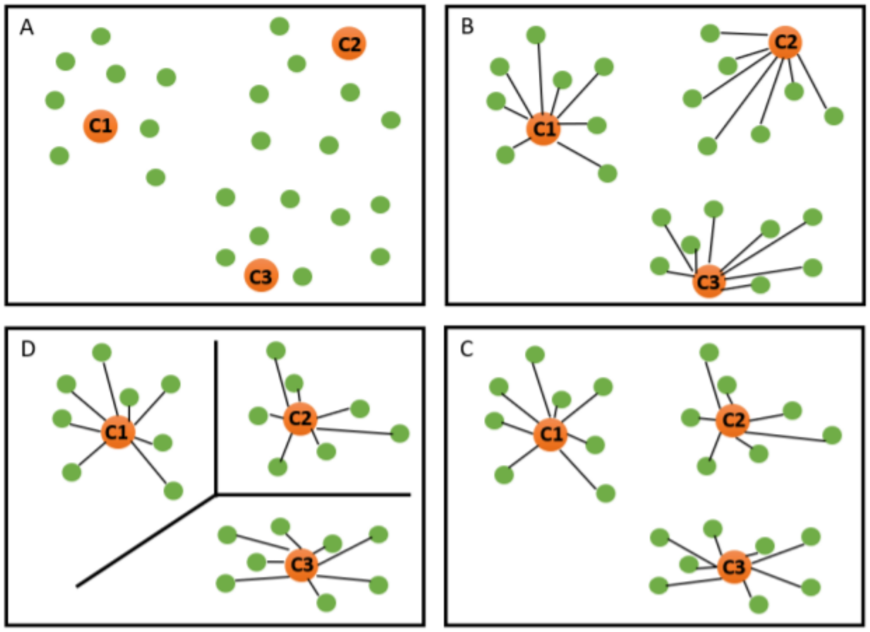


FIGURE 1. **The K-Means clustering process: Three centroids are randomly chosen (a); Objects are assigned to clusters (b); Objects are assigned to clusters (c); The centroids have moved to new positions (d).**

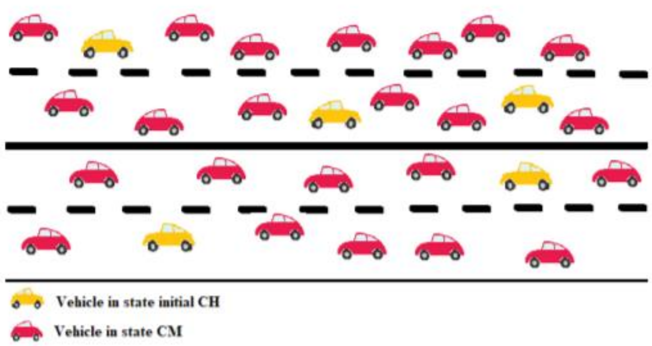


FIGURE 4. **Set of initial cluster heads.**

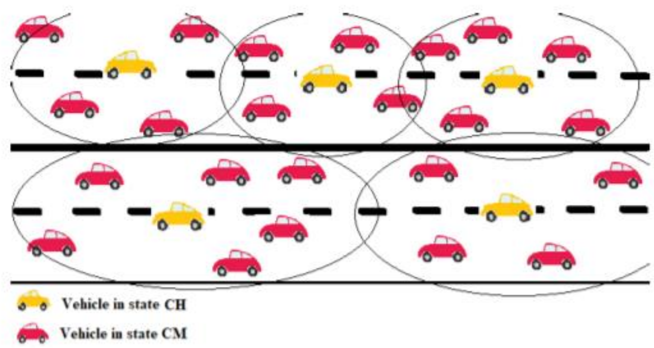
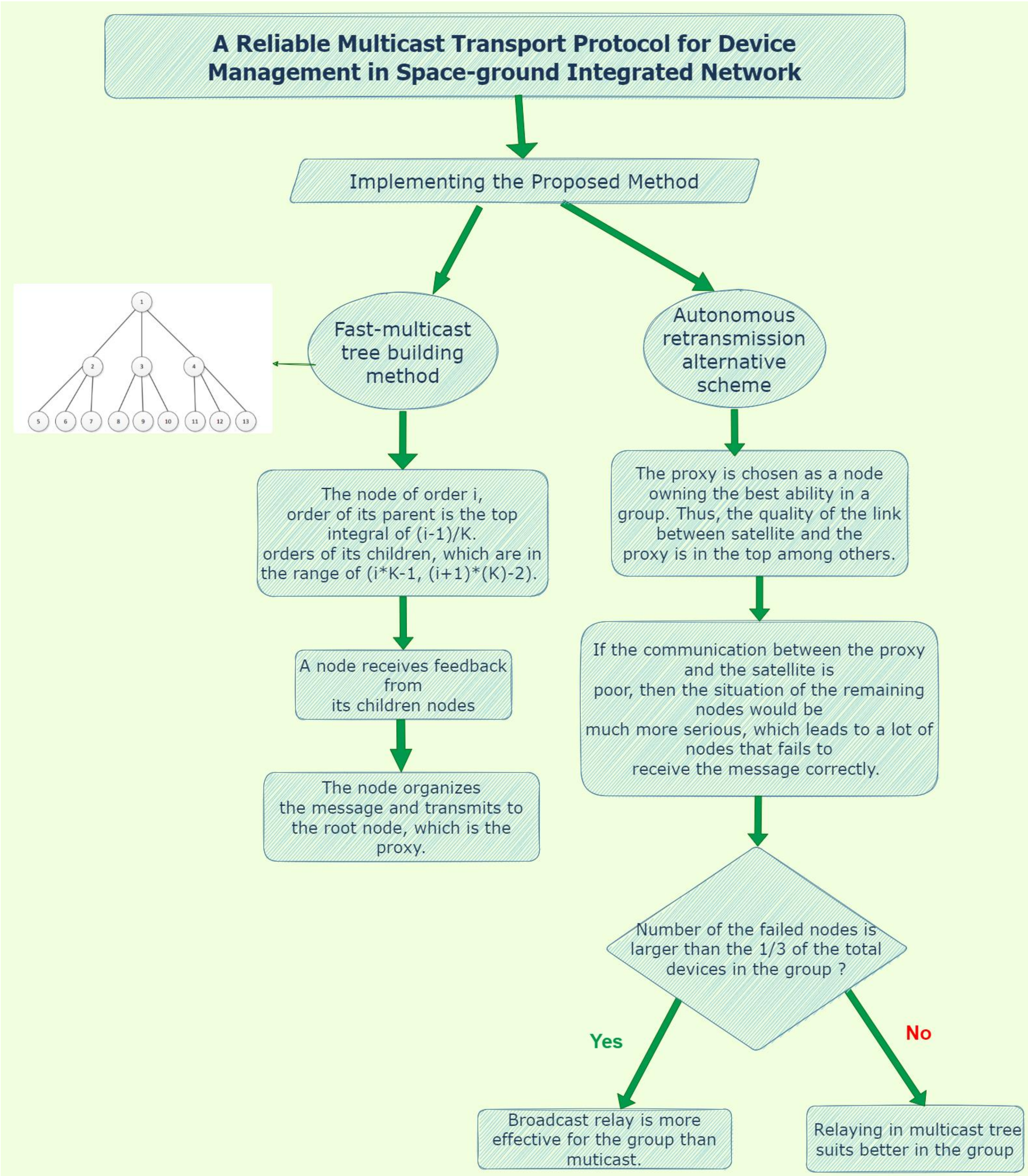


FIGURE 7. **Cluster formation in KMRP.**

c. Flowchart for the proposed approach



4. Performance Evaluation

a. Simulation environment and Parameters

Environment:

ns2, XGraph

Parameter:

Energy Cost, Time Cost, Avg Delay, Throughput, Packet Drop Ratio, Packet Delivery Ratio

b. Performance metrics

MT => Classical multicast protocol TCP Peach++
NC => Broadcast protocol based on network coding
MDM => Our Multicast protocol for device management

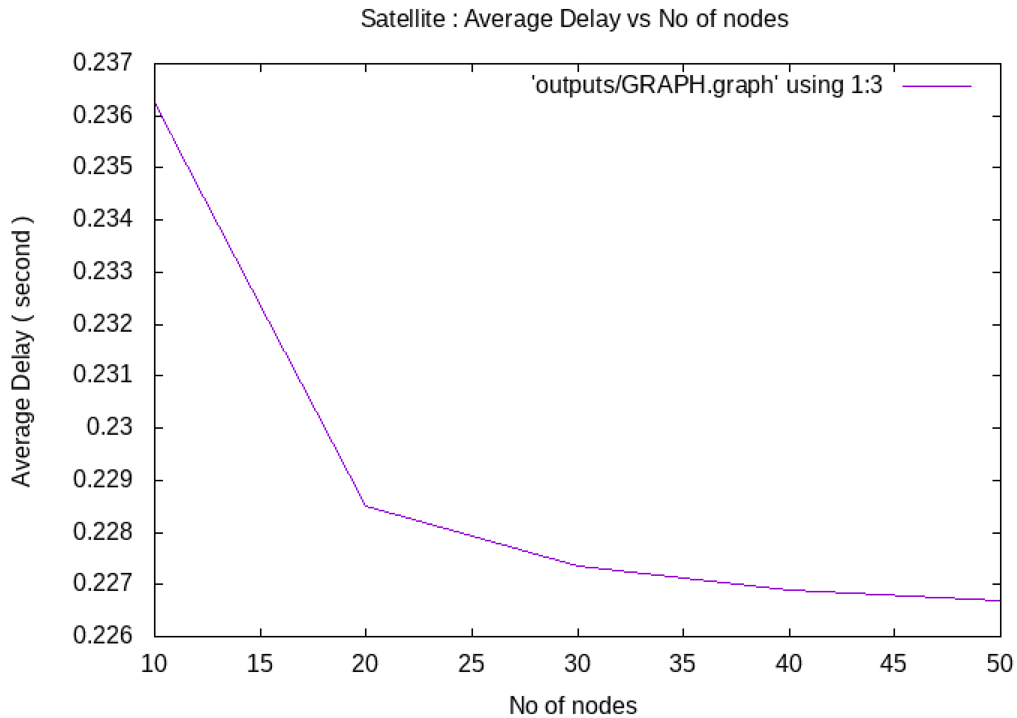
We can see that all methods increase the total energy consumption as the number of nodes in the cluster increases, and the rates of increment of the three algorithms are also similar. However, the MT consumes the most, followed by the MDM, and finally the NC.

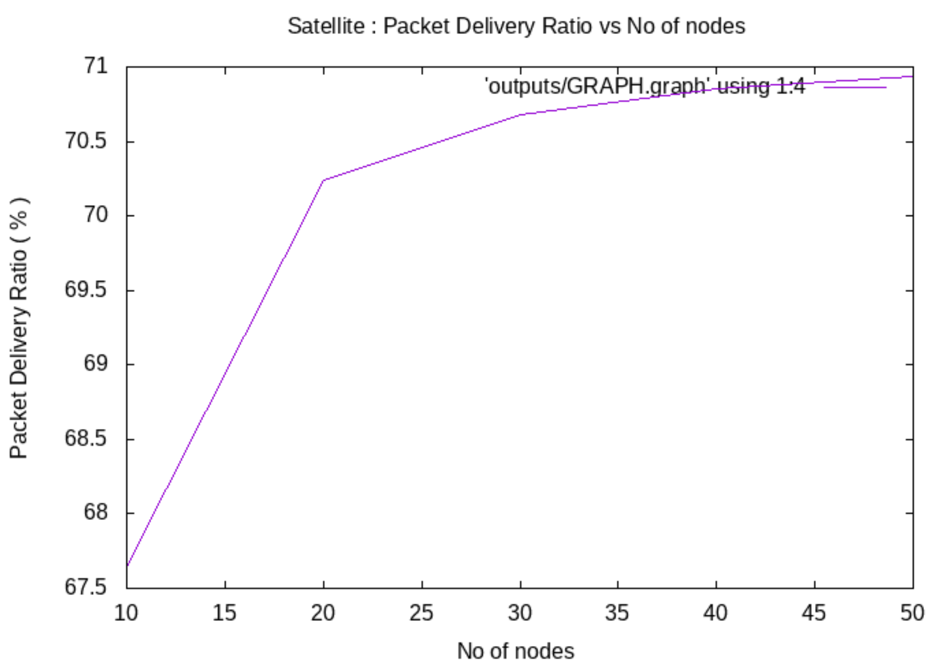
It can be seen that the performance of the MT algorithm in terms of both energy consumption and transmission efficiency is not as good as that of the MDM algorithm. Although the overall energy consumption of the NC algorithm in the experimental process is the lowest, and in the case of a large number of destination nodes, the transmission efficiency of the NC algorithm is also better than the MDM.
While when the number of destination nodes is small or moderate, the efficiency of the MDM is much higher than that of

the NC, and the gap between the overall energy consumption is small.

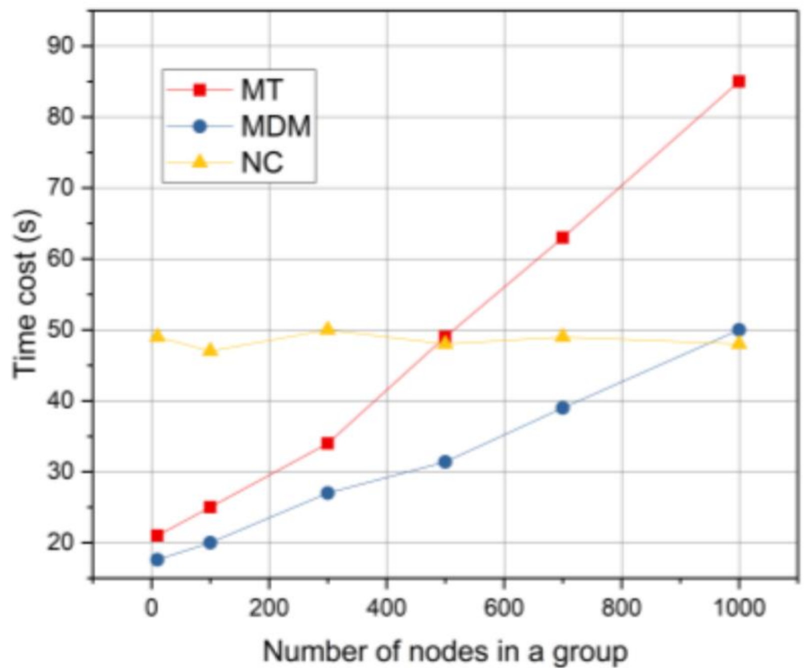
Therefore, it can be seen that in the scenario of policy transmission, the MDM has a greater advantage than the NC.

c. Graphs

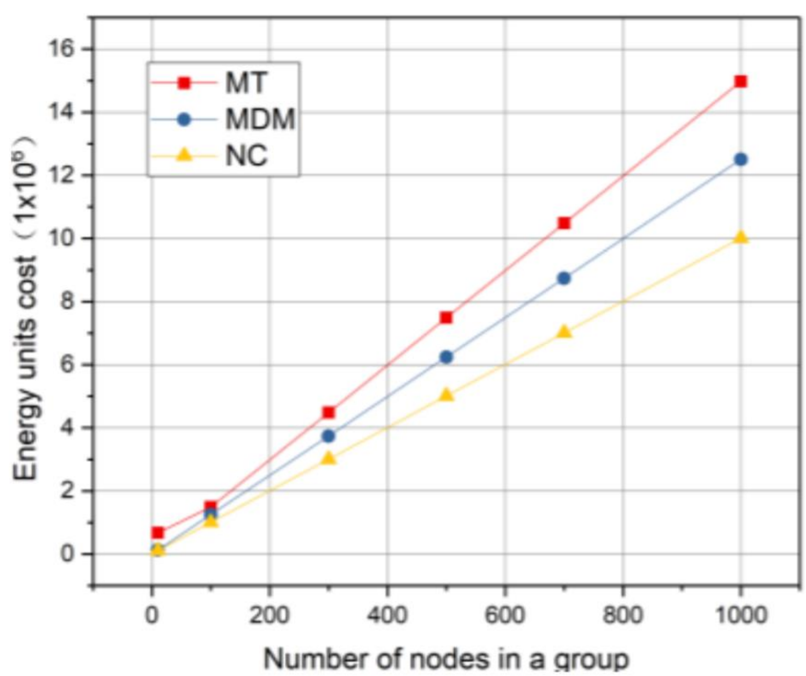


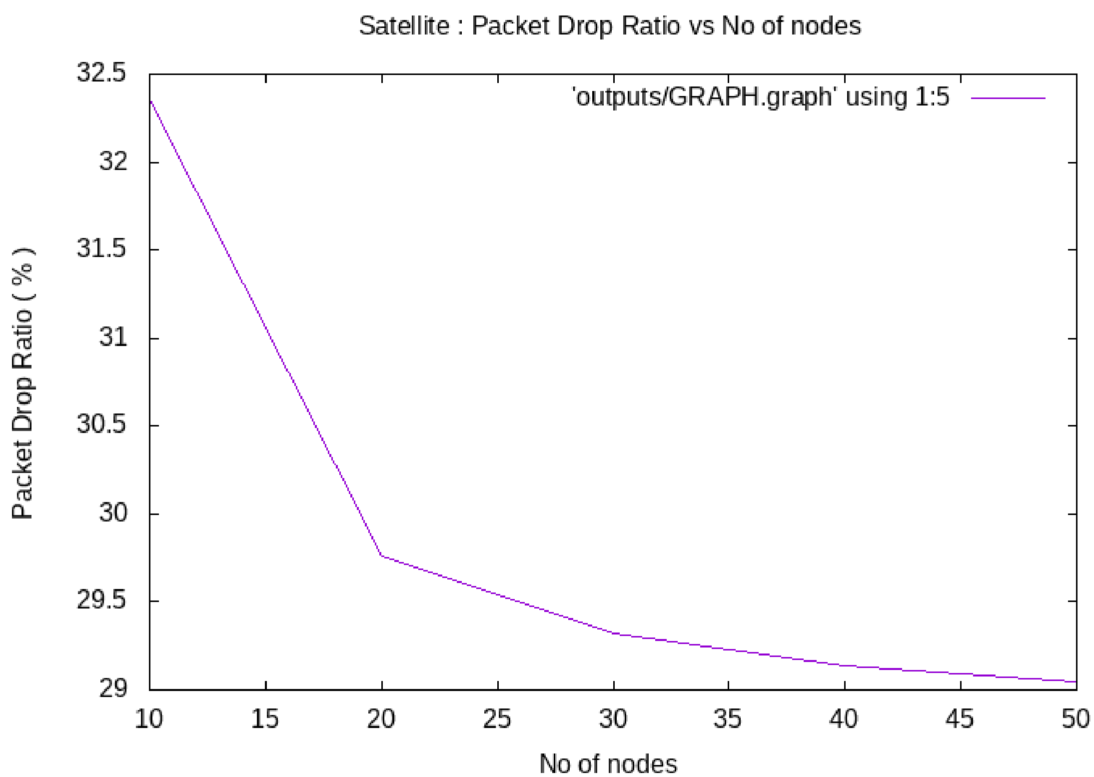


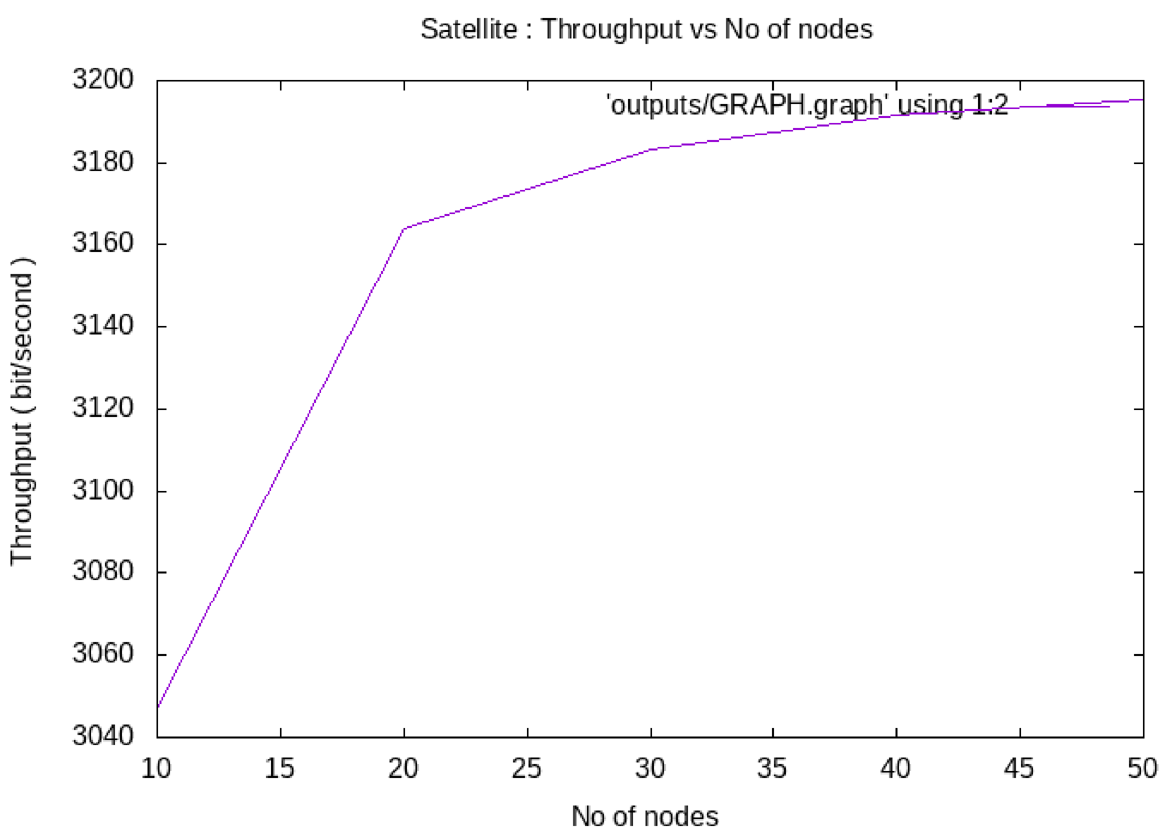
Time cost versus the number of nodes in a group:



Energy cost versus the number of nodes in a group:




Satellite : Packet Drop Ratio vs No of nodes
'outputs/GRAPH.graph' using 1:5
Packet Drop Ratio (%)
32.5
32
31.5
31
30.5
30
29.5
29
10
15
20
25
30
35
40
45
50
No of nodes


Satellite : Throughput vs No of nodes
'outputs/GRAPH.graph' using 1:2
Throughput (bit/second)
3200
3180
3160
3140
3120
3100
3080
3060
3040
10
15
20
25
30
35
40
45
50
No of nodes

5.Conclusion & Future Work

We designed a reliable multicast transport protocol for device management in the space-ground integrated network. The protocol contains acknowledgment aggregation and local error recovery. We designed a rapidly tree-organized scheme for the frequently changed destinations in each message. Also, we designed an evaluation scheme to choose an energy-efficient way of communication for optimizing. Experiments compared with other protocol shows the schemes work well.

Future works can be the election of the proxy node and the optimization in the location, to increase the universality of multicast transport protocol

Also, we want to improve the VANET performance by optimizing the K-means when the traffic is highly dynamic.

6. References

- **A Reliable Multicast Transport Protocol for Device Management in Space-ground Integrated Network**
  https://dl.acm.org/doi/10.1145/3220162.3220173

- **A New Hybrid Routing Protocol Using a Modified K-Means Clustering Algorithm and Continuous Hopfield Network for VANET**
  https://ieeexplore.ieee.org/abstract/document/9382997

NOTE: *All Papers of Related work is mentioned in the above sections*