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Research of different methods of data transmission and their problems in remote areas using magnetometric survey

The goal of the work is to design routing algorithm taken into account overlapping contacts and to perform bundles scheduling.

Introduction and problem statement

Nowadays, Internet become very popular because all people around the world can communicate with each other, delivering internet access to different areas around the world is major point, and major challenge because sometimes is extremely hard to extend network in remote areas as well as extremely expensive.

The first possible solution for this could be the “Ring Road” approach for a low-cost communications satellite network, based on the integration of LEO satellites and Delay Tolerant Networking (DTN) technologies. The Ring Road system is a low-cost communications satellite network designed to provide high-latency and highly robust data interchange capability by using LEO satellites as “data mules” in a network established by Delay-Tolerant Networking.”[1]

The second possible solution can be presented by satellite constellation. A satellite constellation is a group of satellites working in concert; low Earth orbiting satellites (LEOs) are very often deployed in satellite constellations. Many LEO satellites are used to maintain continuous coverage over an area. In comparison with “Ring Road” approach satellite constellation has more

complex computational logic and as a result is more preferable. Examples of satellite constellations include GLONASS constellation for navigation and geodesy, the Iridium , the large-scale Teledesic and Skybridge broadband constellation proposals of the 1990s, and more recent systems such as O3b or the OneWeb proposal, etc."[2]

OneWeb worldwide satellite broadband network has benefit from low-latency communications, so LEO satellite constellations provide an advantage over a geostationary satellite, where minimum theoretical latency from ground to satellite is about 125 milliseconds, compared to 1–4 milliseconds for a LEO satellite; a LEO satellite constellation also provides more system capacity by frequency reuse across its coverage. The disadvantage of having a OneWeb satellite constellation of 700 satellites is cost. While the OneWeb satellites are physically much, much smaller—about 150kg (330lbs) per OneWeb satellite vs. 4000kg (9000lbs) for a geosynchronous communications satellite—it costs a lot to build 900 satellites and launch 700 satellites into space (The extra 200 satellites will be held back on Earth until they're needed).”

It is already known that, ground stations can establish contact with LEO satellite constellations, such as OneWeb or LeoSat, only when the ground station is under coverage area of satellites. Due to large number of LEO satellites and large surface coverage the probability of overlapping contacts of the nodes increases and consequently more data losses happen. The cause why capacity loss of the channel occurs, from technical perspective, is due to the fact that single-antenna installation is incapable to maintain uninterrupted operations from several satellites simultaneously and support of multiple installations is expensive; ground station selects only one satellite at a point in time while the data of another satellite getting ignored. Novel routing algorithm for finding path with minimum capacity losses, earliest delivery time and maximum bit rate in case of overlapping contacts should be found. In the given work different approaches to find path with minimum capacity losses, earliest delivery time and maximum bit rate and to perform scheduling of bundles would be investigated. The major ideas of different routing protocols such as CGR, CGR-ETO, etc. help to develop routing algorithm for routing environment with overlapping contacts. The given work will present approaches, as an enhancement to existing routing protocols, aims to improve performance and minimize costs of the network in the presence of overlapping contacts, as well as approaches for bundle scheduling.

Working principle of proposed algorithm

In order to find out the optimal path by considering not only the shortest distance but also the network losses and to perform scheduling of bundles, the following single processing steps should be examined:

- Step 1. Initial configuration
- Step 2. Selection of highest priority bundle
- Step 3. Finding the max flow value in flow network
- Step 4. Checking the size of bundle
- Step 5. Calculation of optimal path
- Step 6. Finding the max flow value in optimal path
- Step 7. Updates in contact plan
- Step 8. Finding the rest data

In processing step № 1 “sender” should invoke some function in application service to send a unit of application data to a remote ounterpart. The destination of the application data unit should be expressed as a BP endpoint ID. The application data unit should be encapsulated in a bundle. Each bundle should have its own “sender-defined” priority and should be forwarded over selected path build based on the “sender-defined” contact plan.

In processing step № 2 is stating that processing logic should be aware of the priority of bundles to guarantee reduction of transmission delays. Exist different priority levels: 2 = bulk, 1 = normal, 0 = expedited. In the proposed approach bundles of low-priority value should represent top priority.

In processing step № 3 the max flow value in flow network should be calculated. In the proposed approach the Ford-Fulkerson’s algorithm should be used in order to find max flow in the flow network to identify amount of data that can be transferred from one point to another.

In some cases the size of bundle can be bigger than network can transfer in other cases it can be smaller and as a result several bundles can be forwarded, with a help of Ford-Fulkerson's algorithm (max flow value is sum of min flow values of all possible paths to the given destination) bandwidth management can be performed, knowing the maximum flow in the flow network can be predicted the amount of data network can transmit and as a result useful allocation of bandwidth to application data is executed.

It also should be noted that the max-flow value calculated by Ford-Fulkerson's algorithm represents "theoretical" upper limit. Thus, in practical setups it may be the case that the real limit is below the theoretical upper limit (specifically, in multicast scenarios using packet-based forwarding) and as a result fragmentation has to be applied, but in our case proposed approach assumes that theoretical upper limit is the same as real limit.

In order to calculate the max flow value in flow network, the proposed approach should represent a graph which represents a flow network using adjacency matrix representation.

In processing step №4 the proposed approach calculates the size of the bundle. A bundle itself plays an important role. In case when the size of bundle is bigger than max flow value in flow network a bundle can't be forwarded because current network has not enough capacity to enable to service otherwise the processing step №5 activates.

In processing step №5 proposed approach calculates the optimal path.

In order to find out the optimal path that guarantees the minimum of network losses, earliest delivery time and maximum bit rate such components as optimal path finder, contact overlap finder and capacity loss calculator should be applied.

First of all, the contact overlap finder extracts data from a contact plan. A contact is defined as an interval during which it is expected that data will be transmitted by DTN transmitting node and most or all of the transmitted data will be received by contact's receiving node.

Knowing the contact plan of the whole network the overlapping contacts can be easily determined by contact overlap finder.

As was already determined completed bundle transmission or reception activity reduces the current capacity of the applicable throttle by the capacity consumption computed for that bundle. This reduction may cause the throttle's current capacity to become negative. Due to the fact that, in the network with overlapping contacts not only bundle transmission or reception activity reduces the current capacity of the applicable throttle by the capacity consumption computed for that bundle but also contact overlap reduces the current capacity of the applicable throttle by overlap value between two contacts. The capacity loss calculator helps to determine network losses in the presence of overlapping contacts.

Thus, optimal path finder using information taken from contact overlap finder and capacity loss calculator calculates the optimal path.

After optimal path selection processing step № 6 activates. In the processing step № 6 proposed approach finds the max flow value in optimal path and compares this value with size of bundle. If size of bundle is bigger than max flow value then the following problem appears: proposed approach calculates the value of capacity losses with regard to the size of bundle, but in the case when some edge has a lack of bandwidth for transferring bundle of the given size then bundle cut-off happens and proposed approach can't calculate the cost of overlap for overlapping contacts with regard to the size of bundle anymore because the size of bundle was changed. In such situation proposed approach sets the size of bundle to the max flow value in optimal path and returns to step № 5 to calculate correct value of capacity losses for overlapping contacts. If size of bundle is less than max flow value in optimal path then proposed approach moves to processing step № 7.

In the processing step № 7 proposed approach updates central contact plan. It should be noted that due to the application context (DTN), nodes are not able to synchronize their contact plans instantly (every node has an own contact plan independently of the contact plans of the other nodes). Our approach proposes central contact plan for all nodes. Before next bundle selection central contact plan should be updated because as was mentioned above completed bundle transmission activity and contact overlap reduce the current capacity of the applicable throttles by the capacity consumption computed for that bundle.

In processing step № 8 proposed approach finds the rest data. If size of bundle is bigger than optimal path max flow value then proposed approach performs the fragmentation. It is clear that in processing step № 8 the part of bundle that was smaller or equal to max flow value in optimal path was scheduled already, but if size of bundle is bigger than optimal path max flow value then proposed approach subtracts bundle size from max flow value in optimal path (fragmentation) and performs scheduling for the rest of bundle starting from processing step № 5.

Experimental setup

In this section experimental analysis of behavior of the proposed algorithm will be examined.

Based on objective of this work, finding the path with minimum capacity losses, in this section the evaluation of network capacity losses due to path selection with a help of standard algorithm (Dijkstra's algorithm) used in CGR-based protocols and proposed routing algorithm in the network with overlapping contacts should be done. Developed in this work program of optimal path selection in the network with overlapping contacts provides as an output selected path calculated with taken into account capacity losses, bit rate and delivery time. In this section the program output provided by proposed routing algorithm will be compared with program output provided by standard Dijkstra's algorithm regarding network capacity losses.

In the first scenario the following network topology will be evaluated (Figure 1).

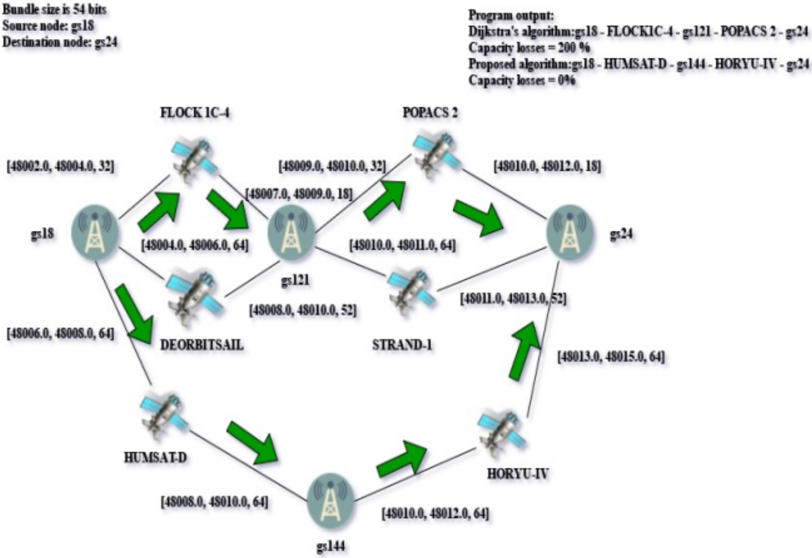

Figure 1 Network topology.

Network architecture (data flow) based on the central contact plan (vertices are nodes and edges are node paths: contacts + vertices), thus given a graph which represents a flow network where every edge has a capacity. After simulation given topology program provides the following output:

- Dijkstra's algorithm
  [['gs18', 'FLOCK1C-4', 0], ['FLOCK1C-4', 'gs121', 100], ['gs121', 'POPACS 2', 100], ['POPACS 2', 'gs24', 200]]
- Proposed routing algorithm
  [['gs18', 'HUMSAT-D', 0], ['HUMSAT-D', 'gs144', 0], ['gs144', 'HORYU-IV', 0], ['HORYU-IV', 'gs24', 0]]

Dijkstra's algorithm selects the path with taking into account earliest delivery time and available link capacity and as a result the following disadvantages arise.

As was already discussed delay tolerant networking routing protocols (CGR-based protocols) does not take into account the overlap factor and resulting capacity losses. In presented example there are overlapping contacts such as: FLOCK1C-4 – gs121 & DEORBITSAIL – gs121 & POPACS 2 – gs24 & STRAND-1 – gs24 in gs18 – FLOCK1C-4 – gs121 – POPACS 2 – gs24 path.

As far as single-antenna installation is incapable to maintain uninterrupted operations from several satellites simultaneously and support of multiple installations is expensive; ground station selects only one satellite at a point in time

while the data of another satellite getting ignored. Thus, capacity losses of gs18 – DEORBITSAIL – gs121 – STRAND-1 – gs24 path are ignored. In comparison with algorithm used in CGR-based protocols proposed algorithm selects another path by taken into account overlapping contacts. Selected path has slightly worse earliest delivery time but in given scenario given path is optimal one.
Thus, can be concluded that path selected by proposed algorithm is optimal due to following reasons:

- bundle is forwarded without losses (high bit rate)
- capacity losses are absent
- transmission delay in comparison with Dijkstra's algorithm is negligible small

Conclusions

Can be concluded that proposed algorithm choose the route that guarantees the minimum of capacity losses, earliest delivery time and maximum bit rate in the network with overlapping contacts.

To validate this work, the implementation of our algorithm was integrated inside environment similar to CGR protocol and was shown that proposed algorithm can be efficiently used in the network with overlapping contacts.

References

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