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Congestion Control in Deep Space Communication

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Abstract: ***Space Exploration has being attracting since early 20th century. Long propagation delay at the planetary nodes introduces new challenges to the congestion control. In this paper we take advantage of long propagation delay, which is utilized as a memory space. Instead of dropping the packets they are sending back to the source, this reduces the packet loss. Two proposed methods in this paper are: Reverse channel with and without rate control will be compared to get the better result.***

Keywords: reverse channel, deep space, space exploration, memory space.

1. Introduction

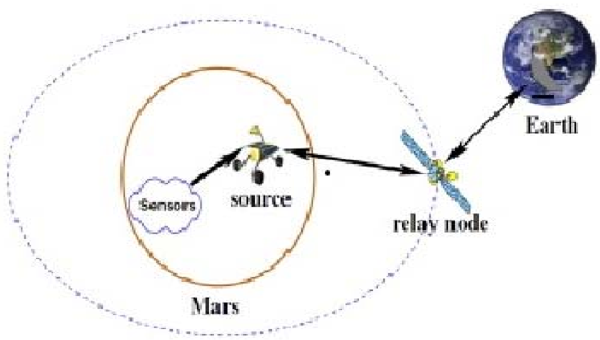
Space exploration is very interesting since early 20th century. There are many private sectors which includes NASA (National Aeronautics and Space Administration), ESA (European Space agency) who have made great efforts to push the space technology forward. The basic mission of space exploration is to successfully transfer a great amount of data which are scientific from other planets/ satellites/ robotics space-crafts as a wireless relay in space. The communication between Earth and other planet forms an autonomous network in the form of store and forward which is integration of multiple networks. We assume in this paper that whatever data that is collected on the planet are stored in a wireless gateway, which is forwarded slowly in a relay at sky, which may be a satellite in the planet orbit. The data is stored in the satellite and whenever possible is sent back to Earth. For example sending multimedia message from Mars surface sensor network to Earth may go through various nodes across many independent networks.

In the picture it depicts that Earth and Mars are the source and the destination respectively. On Mars there is a network sensor where message is collected first and stored in gateway. Before delivering to the final destination i.e. Earth it is sent to the intermediate node multiple nodes can be used in some cases. The picture depicts multiple hopping in interplanetary node. A unique characteristic of space throws a challenge to Deep Space Communication Network. In this three major challenges are shown:

1. Long Propagation delay-There is a long propagation delay between gateway and the destination in space communication which ranges from ten minutes to hour, the reason behind the delay there, is long distance between interplanetary nodes.
2. Connectivity-Planet's position varies with time as it moves around their orbits. The communication gets into trouble as both the nodes are not in the line of sight.
3. Buffer size-There is very limited buffer size for the intermediate nodes. The data in such type of nodes is multimedia message. It is not practical to use the conventional Transport Layer protocol, due to extremely long distance between two nodes. In other words it is useless to use congestion control methods. If a relay node is already filled and a packet reaches their, the packet gets lost and thus a feedback is not obtained about the loss. Our focus on this paper is to utilize this long delay channel as a memory for congestion control. Instead of dropping the packets at the intermediate node due to buffer size, the packets which are already over flown are sent back to the source. This will help to keep the data travelling here and there in the channel itself until the destination node is free to accept the packets.

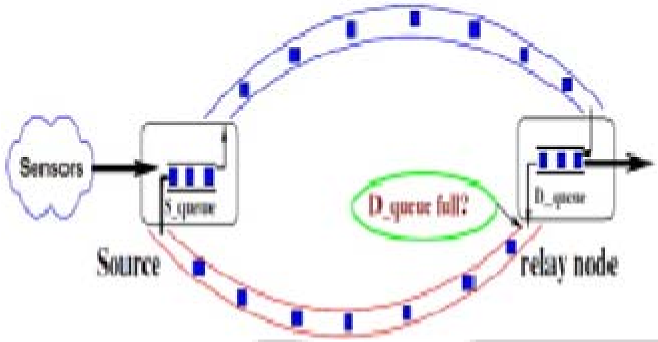
One great advantage is that the packet loss probability is reduced. Most important thing is that it provides a feedback indirectly to the status of congestion in relay nodes. Ones the source gets back the packet it assumes that currently the destination is not free. Therefore it controls the flow of packets from the source. For example the source may say the sensors network to control the transmission or the source may store the received packets and apply a rate control. This method will help to reduce the flow of packets between the source and destination. This method is known as reverse channel with rate control.

The proposed methods are reverse channel with rate control and reverse channel without rate control and then comparing both with the traditional method. In this we have done stimulation which shows that the performance of reverse channel with rate control is better than the traditional method in terms of energy consumption and number of retransmission per packet.



2. System Model

Here we consider two hopping node as a system model in which a source, a destination and a relay node is their. Here we proposed a reverse channel in addition to the forward channel. The source and the relay node both maintains a queue which denotes as s-queue and d-queue. In this d-queue does not have storage which is because of no connection with the destination or when the incoming traffic is more than the outgoing traffic at the relay node. Once the relay node is full, then the packets get lost permanently, this will reduce the throughput. Alternate approach is to use the long delay as a memory space. In other words instead of dropping the packets we can send the packets to the source. Those packets will further join with the new packets at the s-queue and transmit to the nodes again. This process is repeated until the destination is free to accept the packets.



Note to be pointed is that once the source receives the packet it must control the packet flow rate by saying the sensors to slow down their transmission or store the packets in the gateway and slowly apply rate control to the sensors.

Assumptions made in this paper:

1. Nodes are assumed to be static: Planets move slowly but the transmission of packets are more and once the two nodes are in line of sight to each other they stay connected to each other for some time.
2. NACK mechanism: If a packet is lost at the destination due to congestion in relay node, the source is unaware.
3. Dropping of packets due to unavailability of buffer size: For our understanding we assume that no packets are lost due to error in channels. We can make it possible by using a high transmission power.

3. Reverse Channel

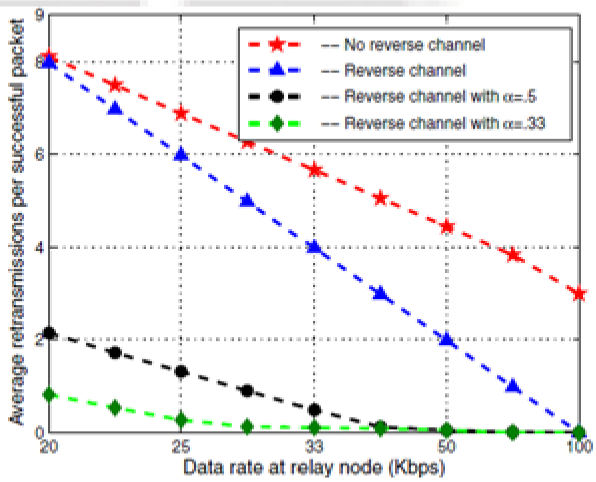
In this we introduce a conventional approach (no reverse channel) and our two proposed system.

1. No reverse channel-Here packets are send in the forward direction i.e. from source to intermediate node. The distance between the source and the intermediate node is very large. Whatever is the status of the intermediate node packets are transmitted from source .If a packet reaches and then comes to know it has less buffer memory then the packets dropped immediately. This will degrades the system .In order to improve the system we have to find alternate approach .In this case the source will send copies as well as the original copies with some time gap so that any one of them will reach the intermediate node successfully. Disadvantage is that this consumes more energy.
2. Reverse channel-Instead of dropping the packets at the destination, the channel between is taken as a temporary buffer and packets are kept in that channel until the intermediate node is available. If the intermediate node is full it just sends the packet back by using the reverse channel. It is a downlink channel. Two advantages are: A.) The packet loss is assumed to be less. B.) We are able to control the packet flow.
3. Reverse channel with rate control- When the source gets the first packet it slows down the transmission. It will say the sensor network to slow down or stores the retransmitted one. The result is total number of packets will controlled and energy consumption will reduce.

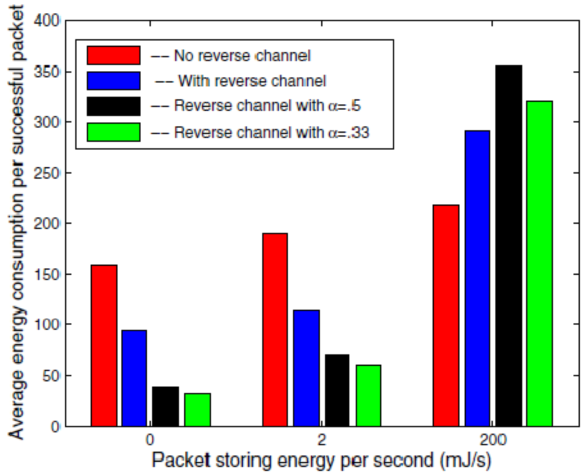
In general energy consumption in transmission is more than the packet storing. Sometimes due to long buffering period and cost of maintaining, the energy becomes more. Therefore we have looked thoroughly for storing energy. Energy consumption depends on many factors like system configuration, hardware specification, operating system, memory management algorithm and so on.

4. Simulation Results

We evaluated the performance of the proposed methods. We used NS2 software as a simulation tool. NS uses two languages because stimulator has two different kinds of things it need to do. On one hand, detailed stimulations of protocols require a systems programming language which can efficiently manipulate bytes, packet headers, and implement algorithms that run over large data sets. For these tasks run time speed is important and turn-around time (Run stimulation, Find bug, and fixed bug, recompile, re-run) is less important. According to our simulation results, energy consumption and average number of retransmission per successful packet are stimulated. The source gathers packet from the sensor network and transmit them to the intermediate node. The intermediate node sends packet to the destination. The intermediate node may send the packet or drop the packet depending on the availability of storage space. We assume that the distance between the source and the intermediate node to be very long. In order to stimulate the congestion at the intermediate node we set it into 50 packets. They are transmitted at a constant rate. If the rate is smaller then it will accumulate at the d-queue. Due to very large distance high power transmission is used in deep space communication. If the storing energy is very high then the reverse channel will also have high energy consumption. It is due to large number of packets are retransmitted back and is kept in s-queue. When we give rate control energy consumption is very high.



Average Energy Consumption per successful packets, E_s=2mJ/s.



Average Energy Consumption per successful packet for different E_s values. R_{dst}=33 Kbps

5. Conclusion

In our previous study there was no reverse channel. The channel was not taken as a memory space. There was limited buffer size. Once the packets are dropped they are lost completely. In this paper we have introduced rate control for sensors by two proposed methods reverse channel with and without rate control. Here the nodes are assumed to be static. There is no acknowledgement mechanics required. After the stimulations are done they are compared to get a better result in terms of energy retransmission per successful packet.

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