Performance Evaluation of MAC Protocols for Data Collection from Planet Mars through Interplanetary DTN-Based Cubesat Network

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Objectives: In the Interplanetary DTN-Based Cubesat network, the Cubesat Nanosatellite as DTN custody node plays the role of Data Mule to collect data from sensors in a Planet such as Mars and the goal of the MAC protocol is to maximize the contact volume which is the amount of data transmitting to the Cubesat during its pass over a service area. This research focuses on the validation of the MAC Protocol analytical models for this type of DTN custody node with the main constraint of its spatial dynamic behavior that depends on the movement of the Cubesat in its orbit and also the rotation period of the Mars planet.

Background:

Interplanetary DTN-Based Cubesat Network is a DTN network (wireless store and forward data collection network) designed for transmitting data from any planet to the earth using Cubesat network. The major constraint in this type of DTN network is that the Cubesat is visible only for a short time (roughly 10 minutes for an orbit of the altitude of 800 km) for a given position on the Mars planet.

System description:

- The visibility time of the satellite by each Relay node in function of revolution period of the satellite $T_{sat}$:
  \[ T_{sat} = T_{s} \times 0 \]
- The speed of the satellite:
  \[ v_{sat} = \frac{2 \pi (R_{sat} + h)}{T_{sat}} \]
- The distance between the two service area extremities of the satellite footprint:
  \[ d_{sat} = 2 \times (R_{sat} + h) \times 0 \]
- The time shift visibility between the two service area extremities of the satellite footprint:
  \[ T_{shift} = \frac{d_{sat}}{v_{sat}} = T_{sat} \]
- The total visibility time of the satellite over a service area is given by:
  \[ T_{total} = T_{sat} + T_{shift} = 2T_{sat} \]

Performance evaluation of Slotted AlohaCA protocol:

Analytical Model results:

\[ M < 1 - 2 \left( \frac{1}{N} \right)^{1/2} \]

Stability condition

Simulation results:

![Simulation results graph]

Conclusion:

- We show that the analytical models of some MAC protocols are not always in good correlation with the simulations results that takes into account the spatial dynamic behavior of the satellite and the planet.
- We reveal that the Slotted AlohaCA protocol is the most suitable MAC protocol for designing DTN Network based on a single Cubesat Nanosatellite.
- A good correlation was obtained between the analytical results and the simulations results only in the case of generated traffic of one packet of 250 bytes per Relay Node per Cubesat pass with a data rate of 1200 bps.
- However, when we increase the generated traffic to four packets per Relay Node per Cubesat pass, the simulations show that the number of Relay Nodes to be deployed in each Cubesat instantaneous coverage zone is reduced to 60 instead of 94 obtained by the analytical model.
- This no-correlation between the analytical model and the simulation results is due to the short period of the Cubesat visibility time over its service area.

References:

5. Forrest Warthman, “Delay-Tolerant Networks (DTN) - A Tutorial”, v1.1, Mars 2003
8. Robert BURMAI, Laurent FRANCK, “Comparaison entre les reseaux mobiles ad hoc et les reseaux tolérants au décalage”