Resource allocation and congestion control in next generation satellite networks

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In order to support high-rate data communication, future satellite networks will have to be designed and optimized for bursty data traffic. This talk will discuss new architectures for satellite and hybrid networks and algorithms for routing, congestion control and resource allocation in these networks. Since satellite resources, such as onboard buffers and energy, are limited, routing and scheduling schemes that make efficient use of energy and reduce the need for buffering are required.

A simple static routing problem arises when the traffic pattern is known in advance. We formulate this routing problem under power and energy constraints as a multicommodity network flow problem with side constraints. An interesting special case of the routing problem arises if one assume that the crosslinks have a large capacity. Then, the problem boils down to choosing the best uplinks and downlinks for any given traffic stream. We are investigating a simplified version of this problem involving a single satellite, with various transmission demands along its orbit. Due to energy limitations, the satellite may not be able to serve all of the demands on its orbit. The objective it to select the demands to be served that maximize overall "revenue". When all of the demands are of equal value it is easy to show that a greedy algorithm that serves demands as long as the satellite has sufficient energy is optimal. However, when non-equal values are assigned to the demands (i.e., revenue for serving the demands differ), choosing which demand to serve is complicated by the need to "save" energy for future more valuable demands. In the case that demands are static and known, we are able to model the problem as a network flow problem and obtain an optimal solution. In the stochastic case, where demands and rewards are time-varying, the optimal solution can be found using dynamic programming.

A different routing problem arises when information gathered on-board the satellite must be transferred to one of multiple ground stations located at different geographical locations (see figure1). The choice of ground station and route is governed by available resources along the route, the utilization of the route, and weather conditions that may affect the ability to communicate to the desired ground stations. We attempt to solve this problem by modeling the system as a network of queues with time-varying service rates. For this simplified model, we are able to show that the queue occupancy is a convex function of the load, and hence solve the optimal load distribution that minimizes the average buffer occupancy. Furthermore, we show that a work-conserving routing strategy that routes the traffic to the satellite that can start transmission first minimizes the worst case buffer requirement on-board the satellites.

Once information arrives at a satellite it must be transmitted along one of its various downlinks. A scheduling problem arises because there are only a limited number of transmitters on-board the satellite; and not all beams can be served by the transmitters simultaneously. Furthermore, transmission along each of the beams may require different power levels and result in different data rates due to local weather conditions that may influence each of the beams differently. The key scheduling problem is how to allocate the transmitters to the different downlink beams and how to optimally allocate power to the beams. In this context we will discuss algorithms that attempt to maximize the satellite's data throughput by taking into account link conditions and buffer occupancies in making the scheduling decisions.

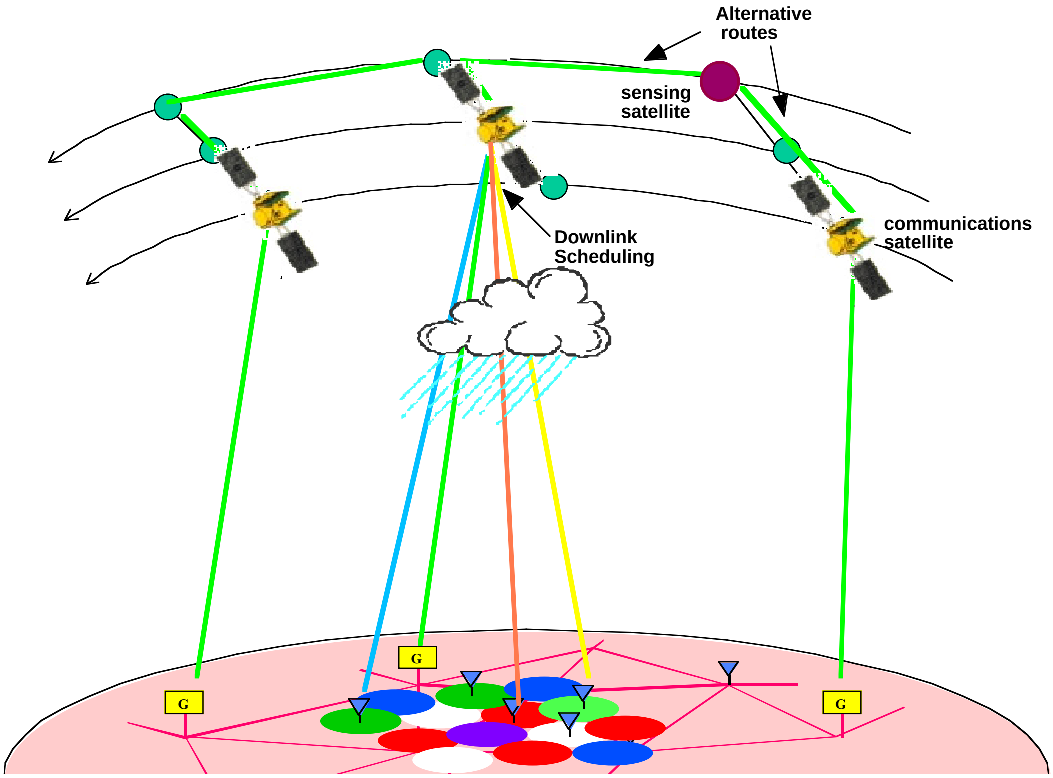

Figure 1. Joint routing and scheduling in space networks.