The Impact of Traffic Prioritization on Deep Space Network Mission Traffic

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Overview

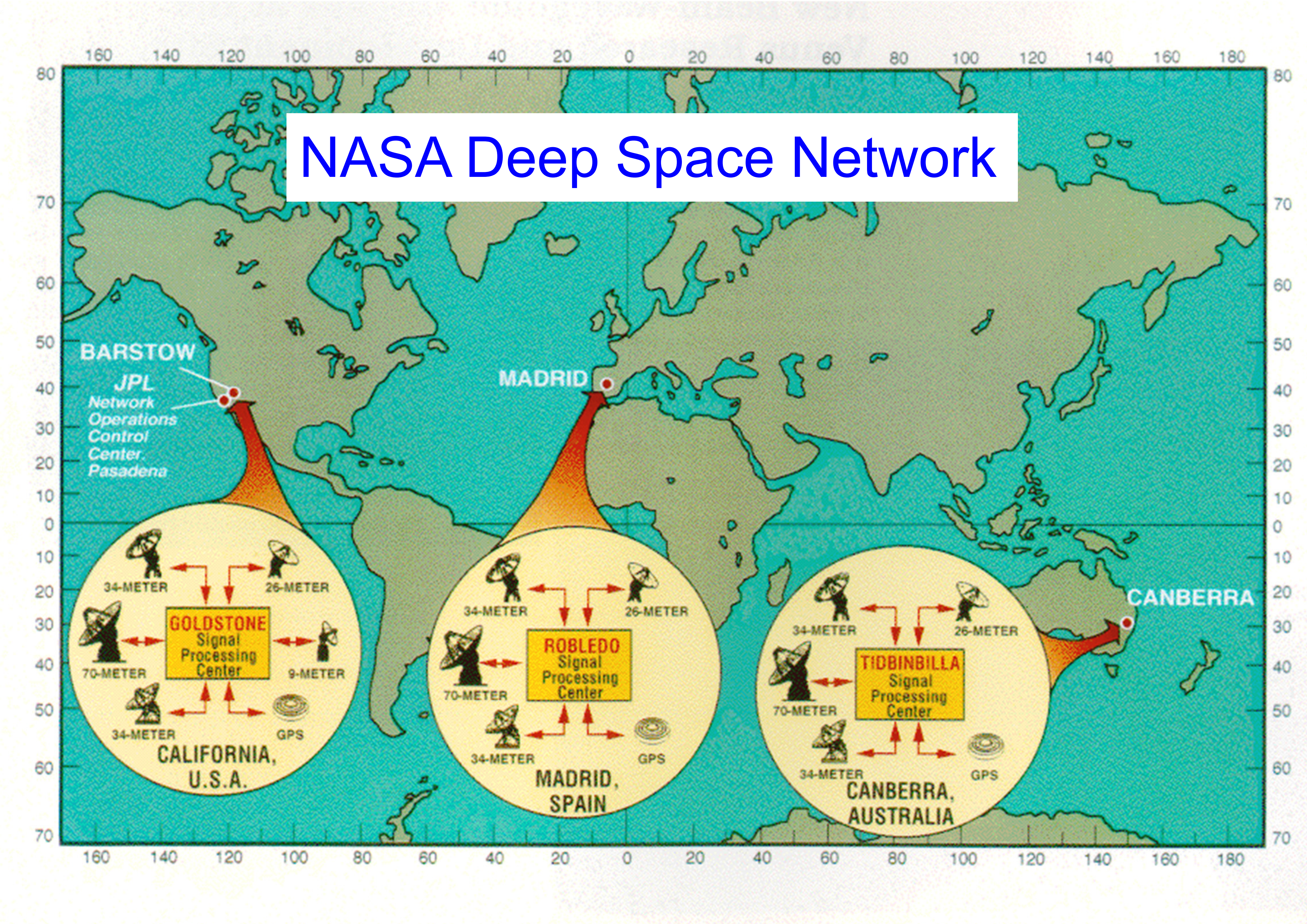
- Deep Space Network Background
- Trade Study and Assumptions
- Simulation Environment
- Models and Methods
- Results
- Summary, Future work

DSN Background

- NASA Deep Space Network (DSN) provides
  - Uplink and downlink data communications and tracking
  - Science services
    - Radio science
    - Radar science
    - Very Long Baseline Interferometry (VLBI)

  - Frame, packet and file services
  - Data transfer from DSCCs to Deep Space Operations Center (DSOC) and to Mission Operation Centers (MOCs) via through
    - Wide Area Network (WAN) generally provided by
    - NASA Integrated Services Network (NISN)
- Three Deep Space Communication Complexes (DSCCs) provide continuous coverage to spacecraft within 10 ecliptic / 15 geocentric declination angles

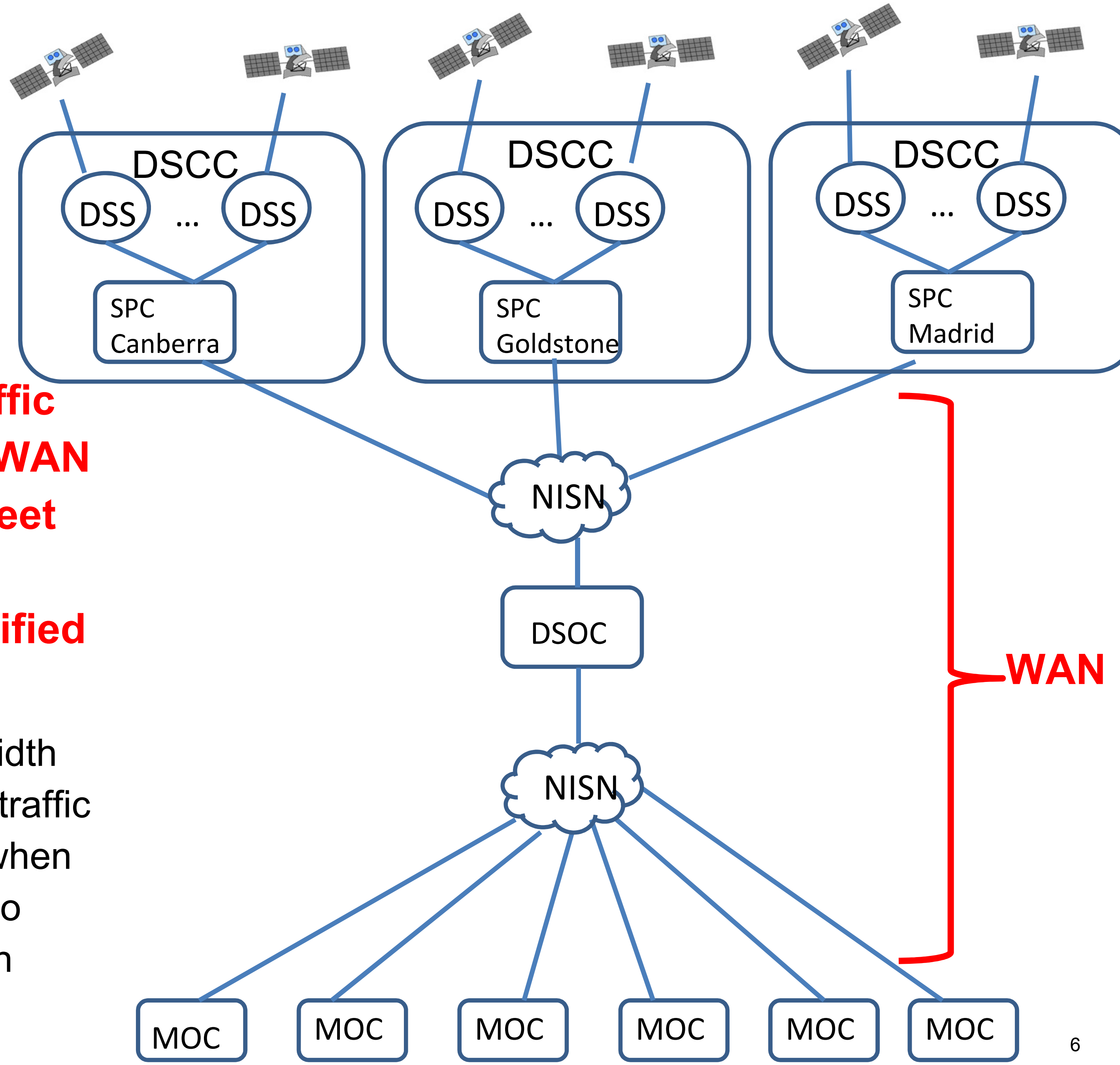
DSN Background



Missions DSN Services

- Missions supported by the DSN are highly diversified, such as their offered data rates
- Space Communications Mission Model (SCMM) forecasts high data rate missions needing DSN support:
  - Joint Dark Energy Mission (JDEM): wide-field telescope, at 150 Mbps
  - James Webb Space Telescope (JWST), at 28 Mbps
  - ExEp-M1, at 7 Mbps
- Mission Quality of Service (QoS) requirements vary
  - Time-critical (engineering health & status or quick-look information): small percentage of total return data
  - Bulk science data with much more relaxed latency requirement
- Although QoS can include reliability aspects, this paper focuses on latency

Trade Study



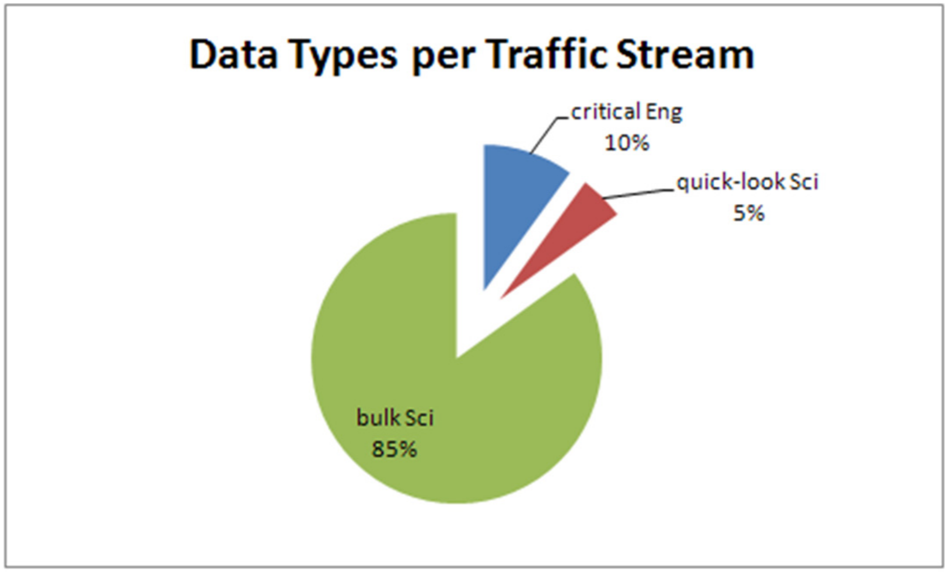
Key question addressed:

- **What is the impact of traffic prioritization on ground WAN bandwidth required to meet latency requirements of different data types specified by user missions?**
  - Compare ground bandwidth required when all return traffic is treated the same vs. when traffic is differentiated into classes and handled with priorities

Trade Study Assumptions

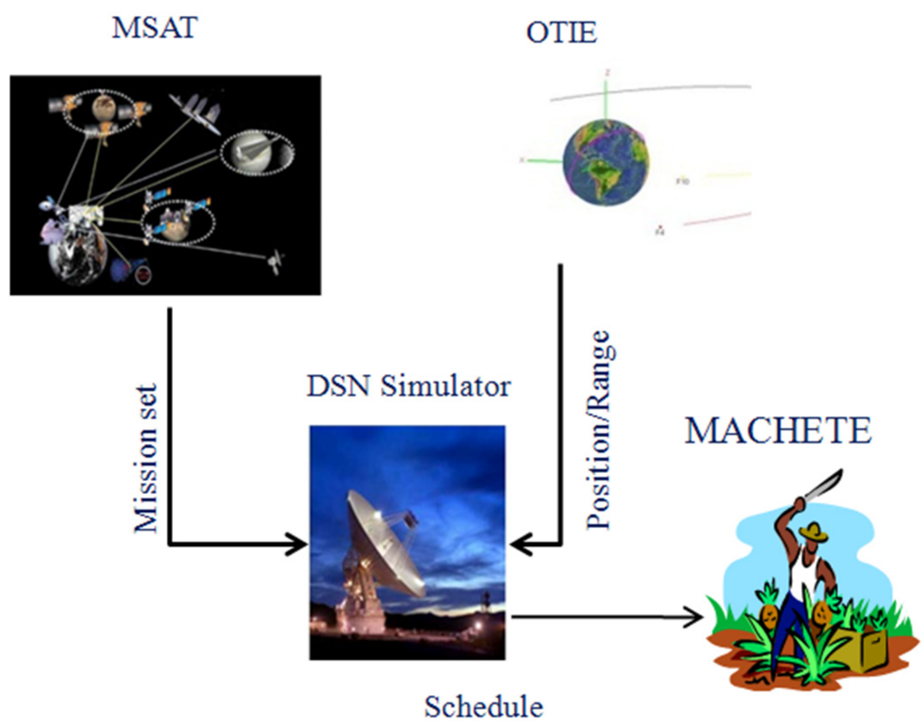
- One month of forecasted mission 2018 traffic
- DSN Systems Engineering group provided the DSN data flow latency estimates, which were incorporated in our simulation model
- Each traffic stream contains the following data types and latency requirements
  - Critical engineering: 10 Seconds (nominal; varied as parameter in trade study)
  - Quick-look science: 30 Minutes
  - Bulk science: 8 Hours

Data Type	Percentage	Latency Requirement
Critical Engineering	10%	10 Seconds
Quick-Look Science	~5%	30 Minutes
Bulk Science	~85%	8 Hours



Simulation Environment

- Mission Set Analysis Tool (MSAT)
  - Extracts mission set from NASA's SCMM tool
  - Analyzes space-ground link characteristics and tracking requirements
- Orbiting Trajectory Inference Engine (OTIE)
  - Visibility files for each mission relative to DSN ground tracking stations

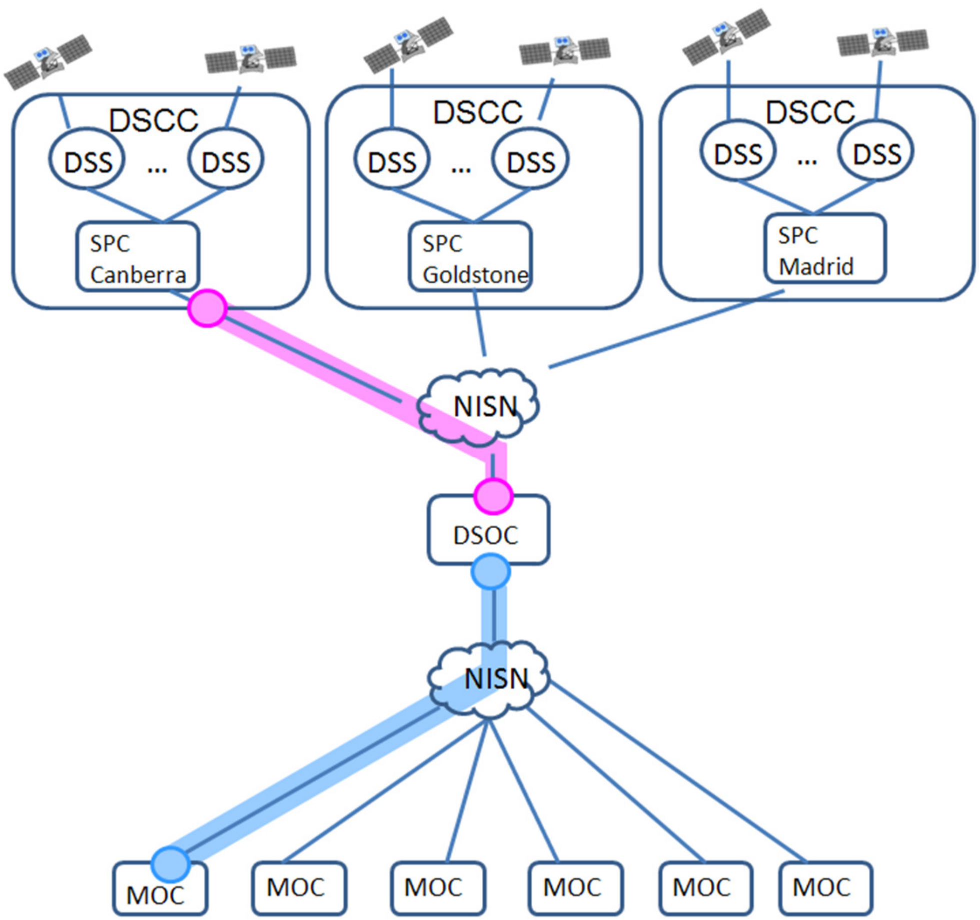


- DSN Simulator
  - Obtains link budget and tracking requirements from MSAT
  - Obtains visibility files from OTIE
  - Generates simulated schedule for each mission's ground station contacts over the time frame of interest
- Multi-mission Advanced Communications Hybrid for Test and Evaluation (MACHETE)
  - Aggregate return data transferred from each DSCC to DSOC to size DSCC-to-DSOC links
  - Individual spacecraft mission data is de-multiplexed at DSOC to size DSOC-to-MOC links
  - TCP/IP-based protocol on ground
  - Buffering at SPC to extent allowed by latency requirement

Simulation Models

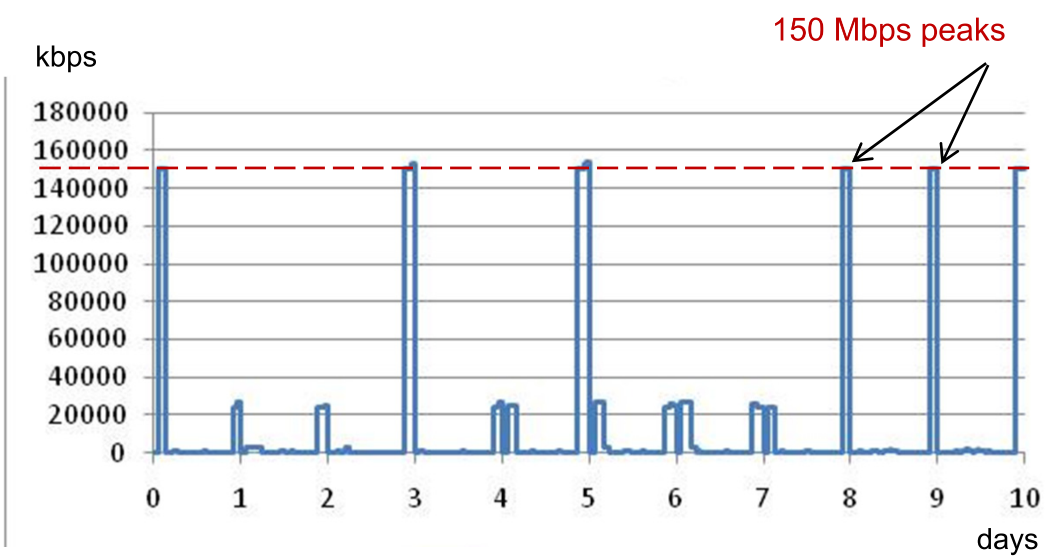
Data Transfer Model

- DSCC to DSOC (pink) paths and DSOC to MOC (blue) paths are modeled as abstract links for bandwidth analysis



Data Traffic

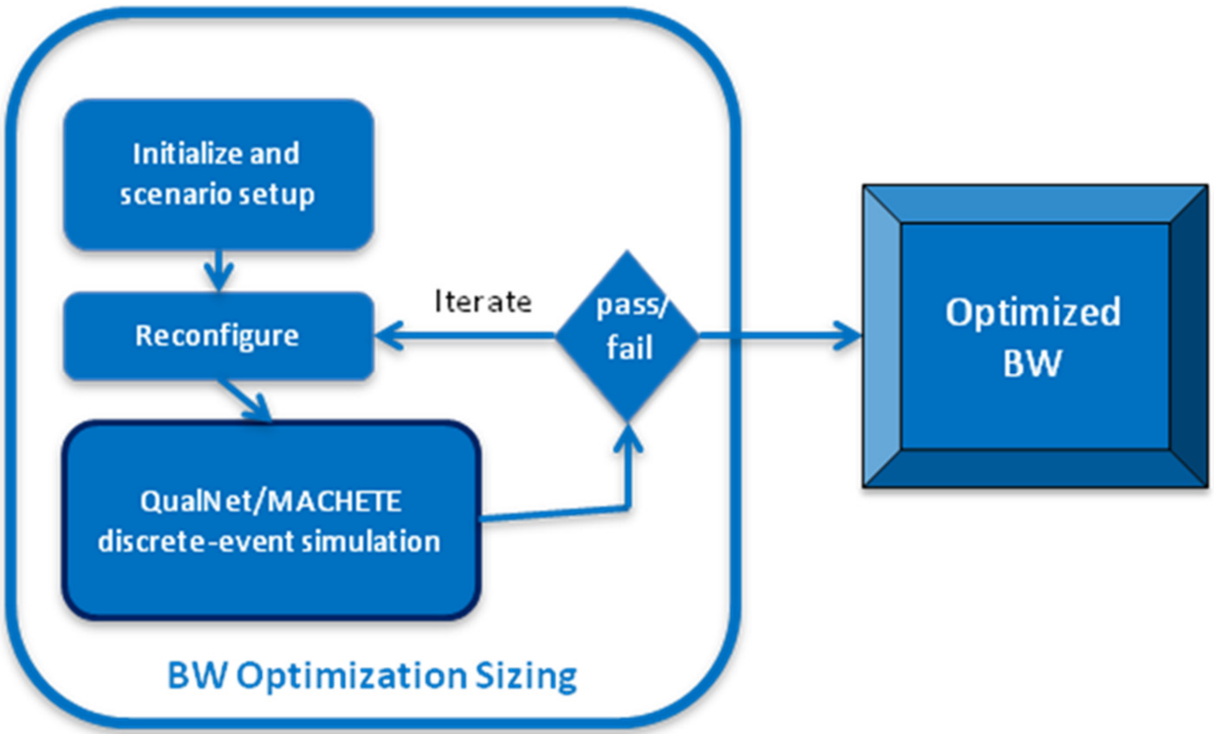
- Simulation includes all predicted DSN mission data from SCMM
- Representative JDEM mission data dominates other mission traffic



Sample mission traffic for DSCC

Experiment Method

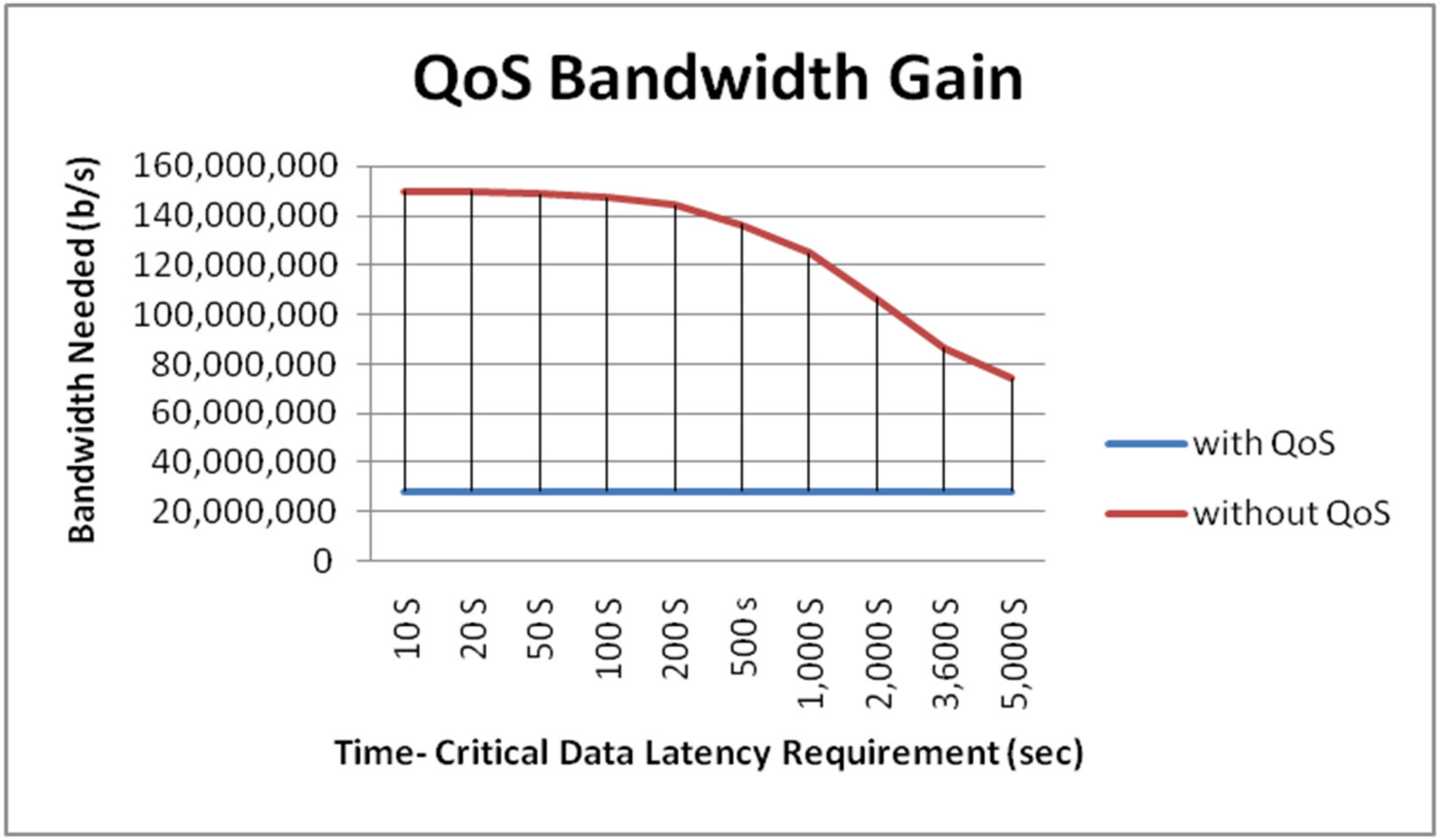
- Premise:
  - Handling all traffic identically (without QoS) means imposing the most stringent latency requirement on all traffic
  - What is the achievable bandwidth reduction when QoS differentiation is applied by the DSN service provider?



- Method:
  - Two sets of experiments: one applying QoS, one without QoS
  - Iterative bandwidth optimization for both sets of experiments: the bandwidth selected, for each link, for the next iteration depends on the latency and data loss statistics gathered from the current iteration
  - User specify a bound on the number of iterations to run; the output is the lowest bandwidth for each link satisfying both latency and no data loss requirements from all iterations

QoS Bandwidth Gain: DSCCs to DSOC

- How does latency requirement on critical data affect bandwidth required?
- Observation:
  - QoS bandwidth gain is most prominent when critical data's latency requirement is much smaller than the latency requirement of other data types.
  - We observe a factor of 3 to 5 bandwidth reduction when QoS is deployed

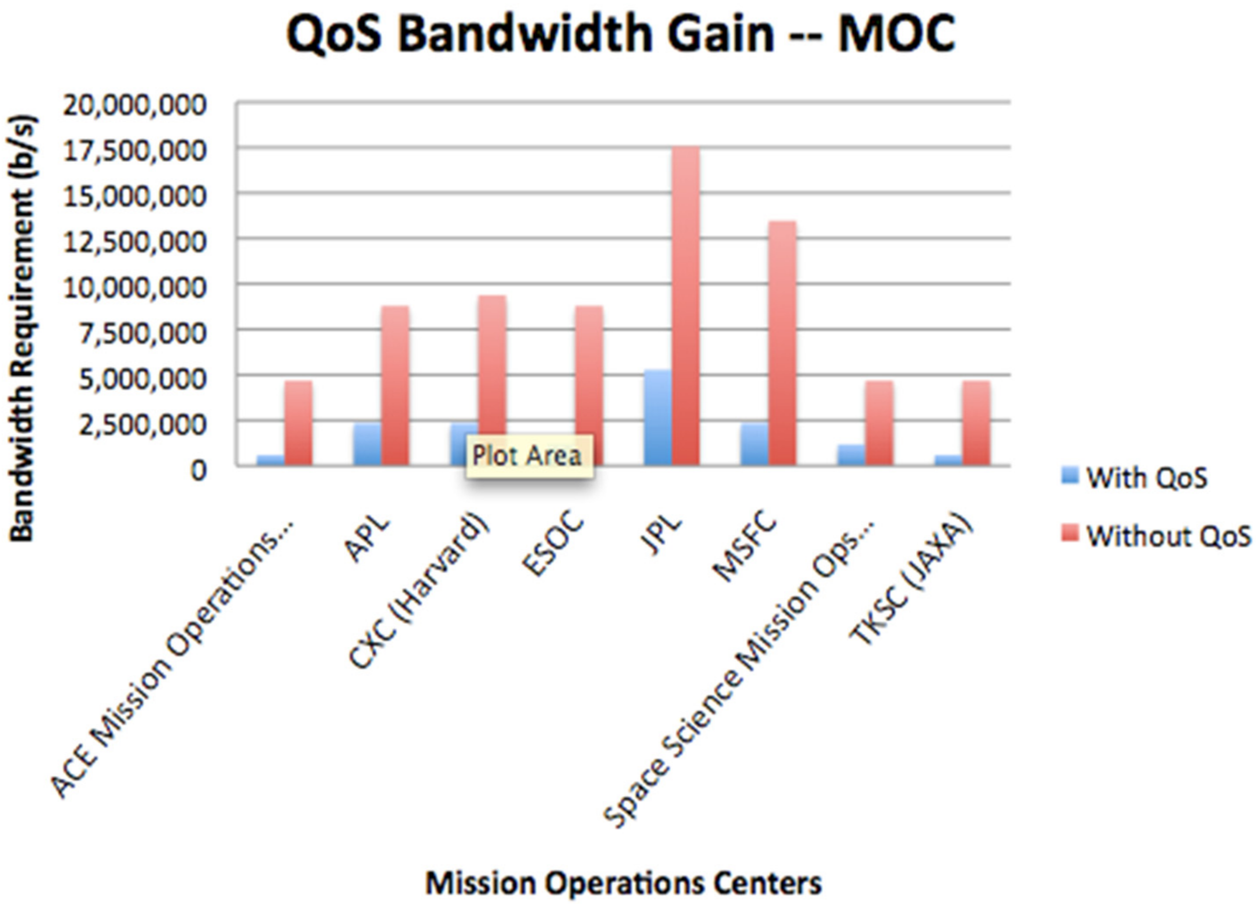


Note: analysis is made for all DSN DSCCs and for all DSN missions in a 10-day period; the plot only shows the Goldstone DSCC to DSOC result

Goldstone DSCC to DSOC bandwidth analysis

QoS Bandwidth Gain: DSOCs to MOCs

- Issue:
  - MOCs have different distances from DSOC → different WAN service costs
  - Fairness issue optimization in combining both DSCC-DSOC and DSOC-MOC links
- Method: two-pass iterative bandwidth optimization
  - Pass 1: optimize DSOC to MOC links
  - Pass 2: apply iterative bandwidth optimization of DSOC to MOC links



- Observation:
  - Bandwidth reduction by a factor of 2 to 8 on DSOC to MOC links when QoS is utilized

Conclusions

- NASA Deep Space Network serves missions with high variance in demand (data rate and burstiness)
- DSN ground stations and MOCs supported span the globe and are connected by a WAN
- Mission traffic types vary by latency Quality of Service requirements
- Analyzed minimum WAN bandwidth required if DSN is QoS-aware (i.e. uses prioritization queueing) or not
- Determined that very substantial bandwidth savings are achievable by introducing basic prioritization mechanisms into the data transfer service