D-RATS 2011
RAFT Protocol Overview

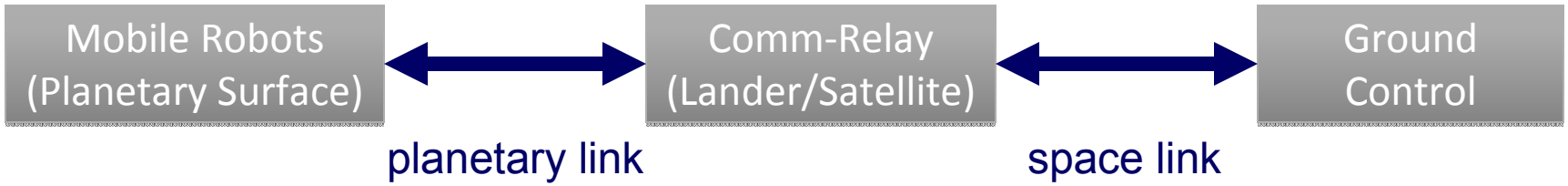
Hans Utz

- Did his doctoral research on the deployment of distributed system middleware on autonomous mobile robots
- Is working at the Intelligent Robotics Group at NASA Ames Research Center as the Rover-Software Lead
- Member of the inter-center RAPID (Robot API Delegate) team working on a common high-level APIs for interoperability of robots from different NASA centers
- Lead architect of the RAFT (RAPID Advanced File-Transfer) protocol

Consultative Committee for Space Data Systems

RAFT Target Scenario

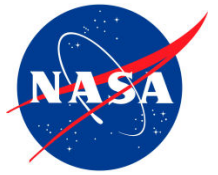
- Planetary robot(s) sending data back to ground-control
- More data products available than bandwidth
- Data downlink most likely over a comm-relay
- Two-hop topology
  - High latency, fairly reliable space link
  - Low latency planetary link(s) with big fluctuations in reliability
  - Differing/varying bandwidth availability on each hop
- Medium latency: 1.7 – 50 seconds (Lunar/NEO)
- Online adjustments to data-product prioritization



RAFT Requirements

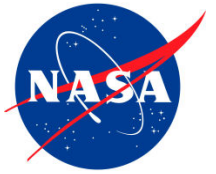
- Optimal/full utilization of allocated bandwidth
- High flexibility in data-product prioritization
- High degree of automation
- Latency-tolerant interface
- (x)GDS integration
- Observability of the system/data-flow

RAFT Design



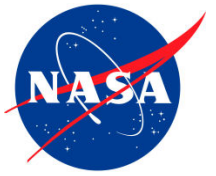
- Multiple channels with token-based bandwidth allocation
- Priority queue on each channel
- Pre-fetching on the planetary network (pull-model)
- Data-products are announced on the planetary network by data-producers
- (Remote) commands:
  - Put, Remove
  - Pause, Resume
  - Set bandwidth
- Auto-queuing
  - Uses file-name and meta-data based rule-set to select default priorities and queues

RAFT Communication



- Shared information space (DDS)
  - White-board style: instances of data organized by topic
  - Updated through a pub/sub architecture
  - QoS dimensions per topic: reliability, durability, history, …
- RAFT file-announce topic (reliable, durable)
  - Availability, location and size of files
- RAFT state topics (reliable, durable)
  - Queue state: file and data volume
  - Sample state: queued, pre-fetching, active, done
  - Receiver state: file and data volume, cache size (best effort)
- RAFT file sample topic, reliable
  - Chunks of files with id

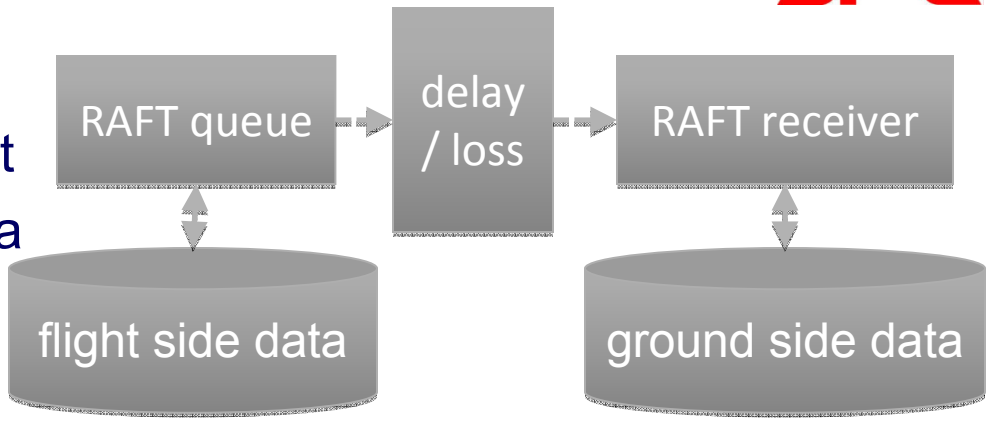
RAFT Implementation

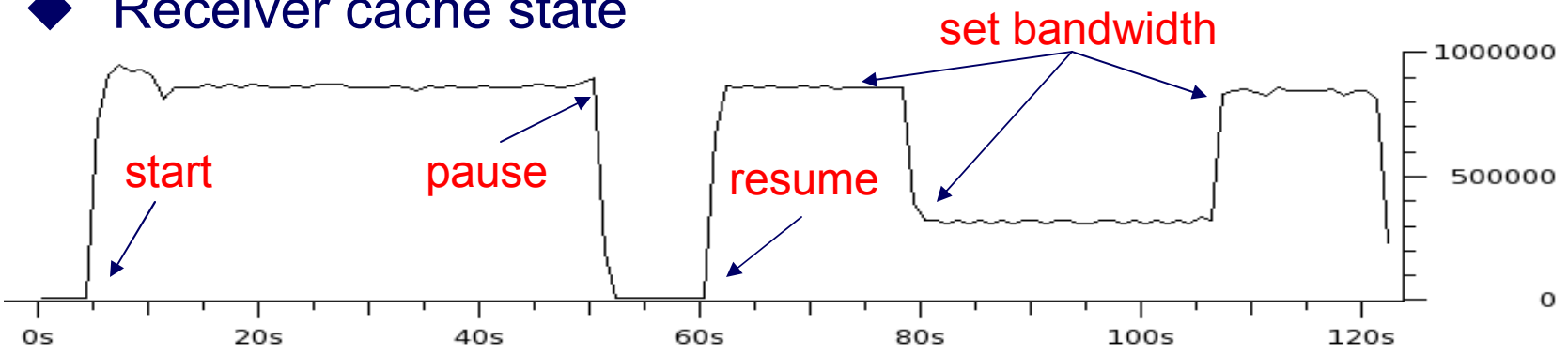


- DDS/RTPS2 used as distributed systems middleware
  - reliability protocol (ack/nack based) over UDP
  - extended the protocol to work with huge bandwidth-delay product (50 s * 10 MBit/s)
  - used for file-transfer as well as meta-data (RAFT state) communication
  - Token-bucket based flow-control for bandwidth management
- C++ implementation (file queue and file receiver)
- libCurl (scp) used for pre-fetching
  - can specify bandwidth-limits in the library
  - kernel-level limits would be more appropriate
- Java/Eclipse front-end
- Web-frontend

RAFT Results: Lab

- Reliable communication over varying bandwidth, latency & packet-loss
  - 100ms, 1.7s, 50s delay
  - 0%, 1% loss, disconnect
  - 250 MB to 1.5GB of data
- Uniform bandwidth utilization
- Adherence to bandwidth limits
- Burstiness (application space) due to total ordering
- Receiver cache state





RAFT Results: D-RATS 2011

- Extensively used for data-download
  - 800 data-products
  - 12.500 files
  - 9.5 GB
- Full xGDS integration
  - Automated science data processing
  - Web based RAFT status-display
- Data from 8+ data producers
  - 2 robots
  - 4 suits (2 laptops)
  - 2 GigaPan Voyage installations