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Communication Networks

Software-Defined Satellite Networking Based on Map'n'Encaps with Segment Routing (SDSN-MSR)

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esa

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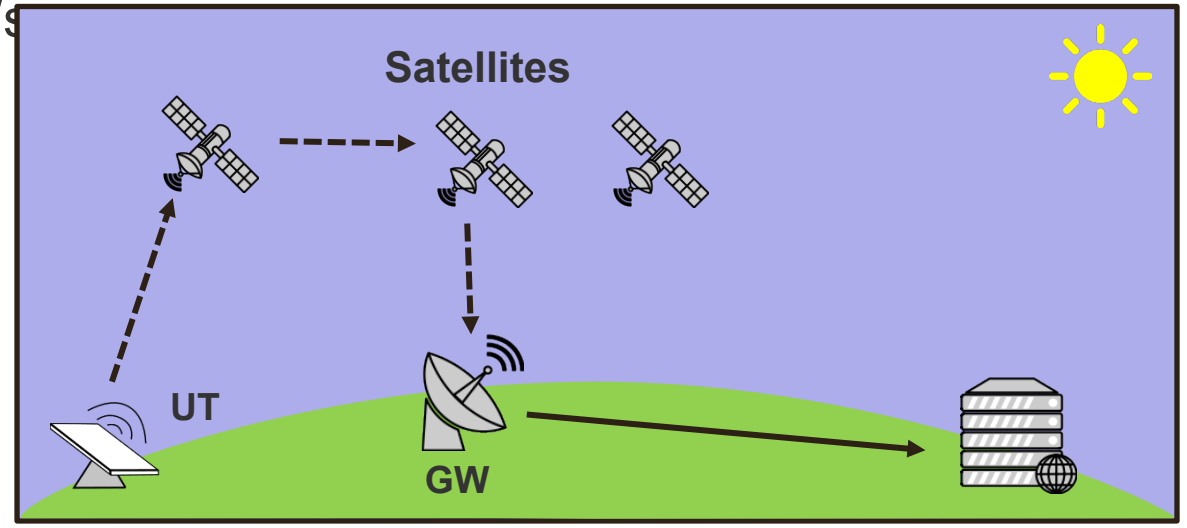
Overview

- Entities and requirements
- Addressing
- Basic operation
- Mapping and forwarding information
- Traffic engineering use cases
- Conclusion and future work

Entities and Requirements

- Entities of the routing architecture
  - User terminals (UTs) not involved in the routing system
    - For simplicity
    - For security
  - Gateways (GWs) connect to Internet or a 5/6G mobile core
  - Satellites relay pkts between UTs and GWs
    - Only simple pkt forwarders
    - Use segment routing (SR)

- Traffic engineering (TE) for
  - Delay reduction
  - Load balancing
  - Offloading
  - Fast rerouting



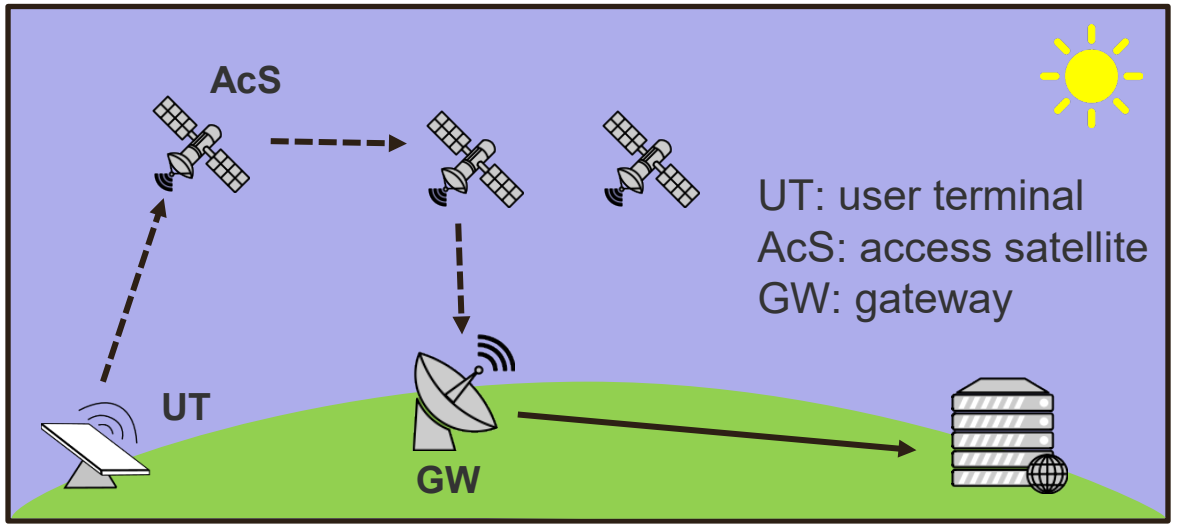
User terminals may be access node for other users

Gateway

Internet node

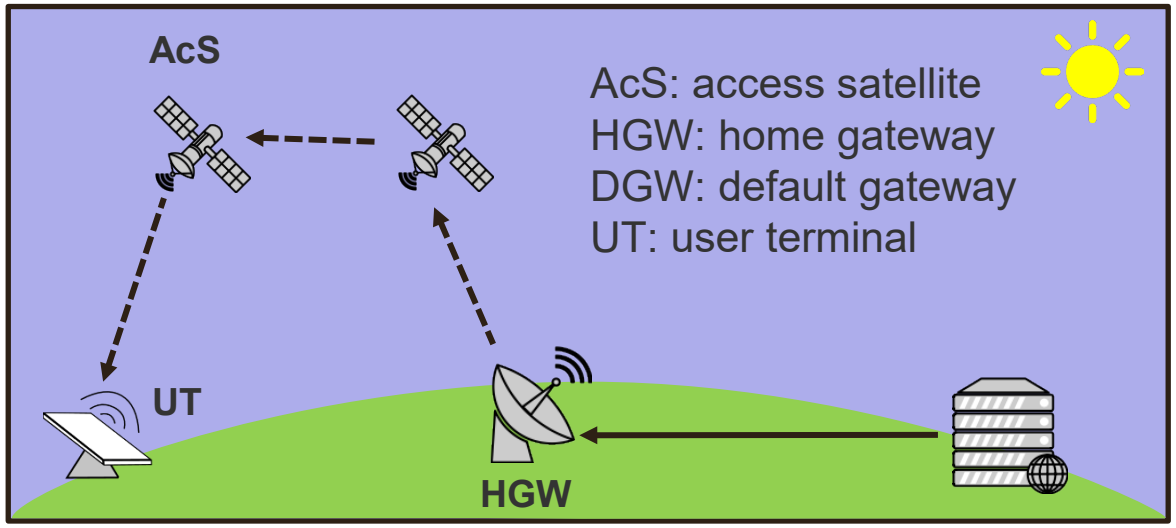
Addressing

- Satellites
  - Segment IDs (SIDs)
- GWs
  - SIDs inside constellation
  - IP addresses towards Internet
- UTs
  - Connected to one (or more) access satellites (AcSs)
    - Change over time
  - Have IP addresses from address block of a home GW (HGW)
    - Announced via BGP



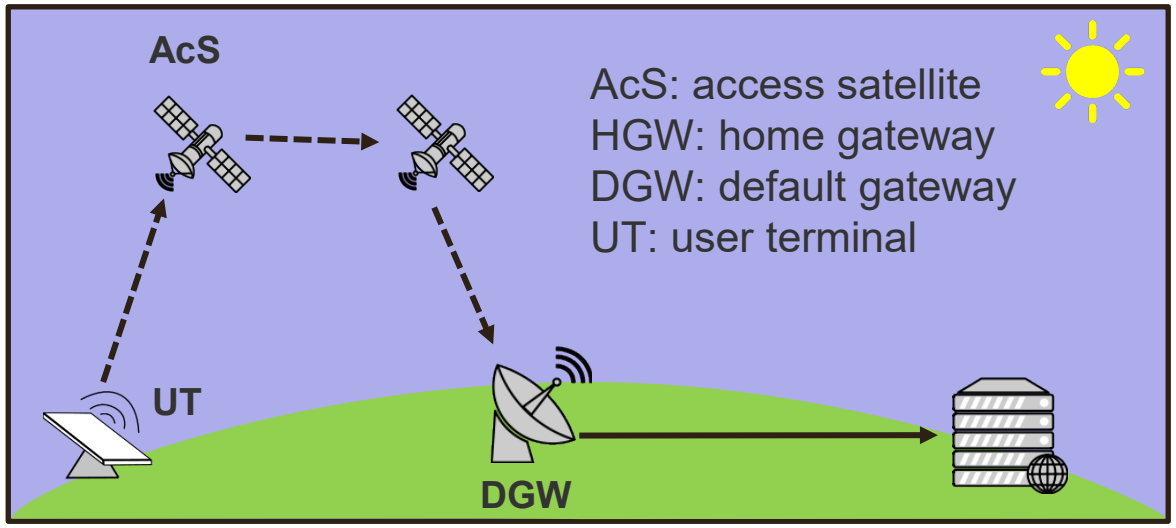
Basic Operation: Internet Node → UT

- Internet node
  - Sends IP pkts to UT
  - Pkts forwarded to UT‘s home GW (HGW)
- HGW
  - Knows UT‘s AcSs and paths to all satellites
  - Pushes SR-header to UT‘s AcSs onto pkts and forwards them
- Satellites
  - Forward pkts using SR
- AcS
  - Forwards pkts to connected UT



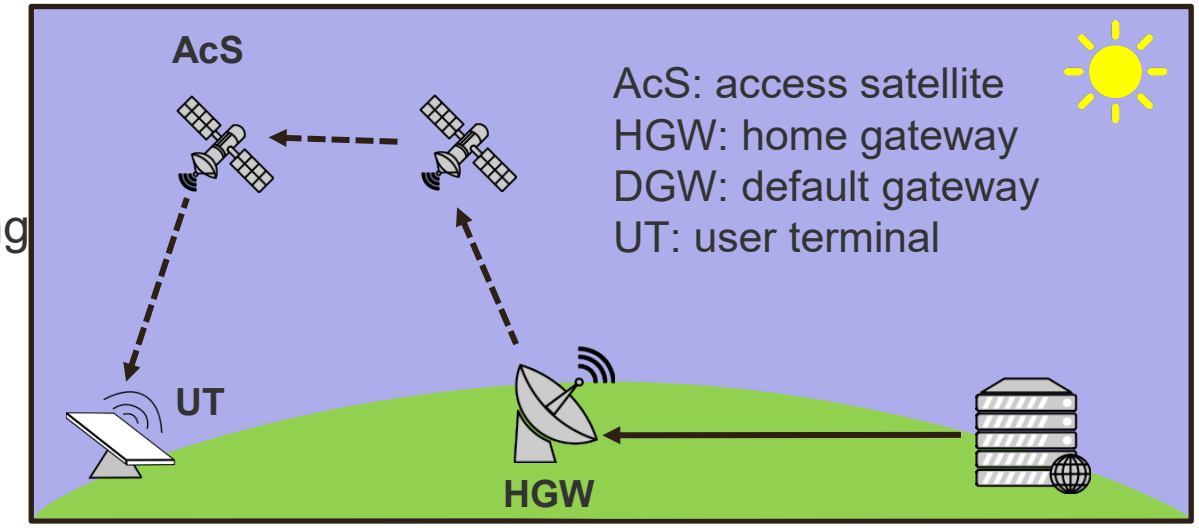
Basic Operation: UT → Internet Node

- UT
  - Sends IP pkts to AcS
- AcS
  - Has configured default GW (DGW)
  - Pushes SR-header to DGW onto pkts and forwards them
- Satellites
  - Forward pkts using SR
- DGW
  - Forwards pkts to Internet

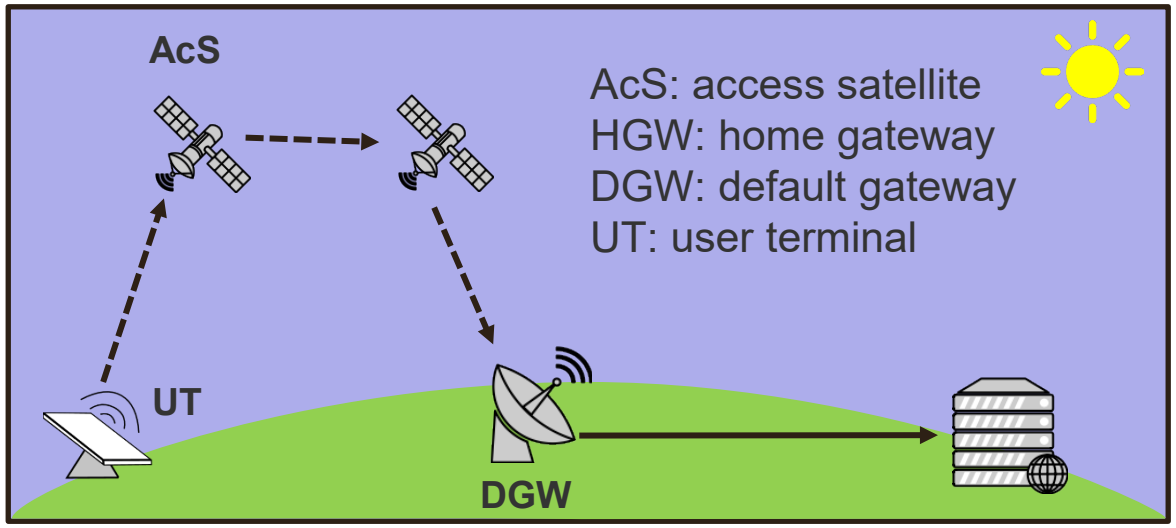


(Map‘n‘)Encaps Information in HGW and AcS

- Map‘n‘encaps info in HGWs
  - Updated by controller
    - Knows entire satellite constellation
    - Is informed about UT‘s AcSs by some signalling
  - Mapping UT → AcSs changes
    - When UT has a handover to next satellite
  - Paths from HGW to satellites change
    - When HGW has a handover to next satellite

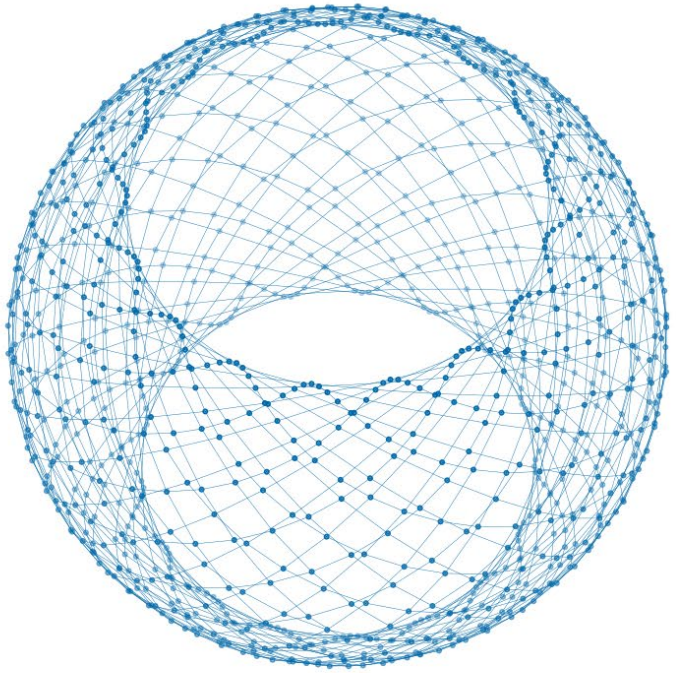


- Encaps info in satellites
  - Updated by controller
    - Knows entire satellite constellation
    - Updates DGW of controlled satellites
  - DGW may change when better DGW is available
  - Path from satellite to DGW changes
    - When DGW has a handover to next satellite



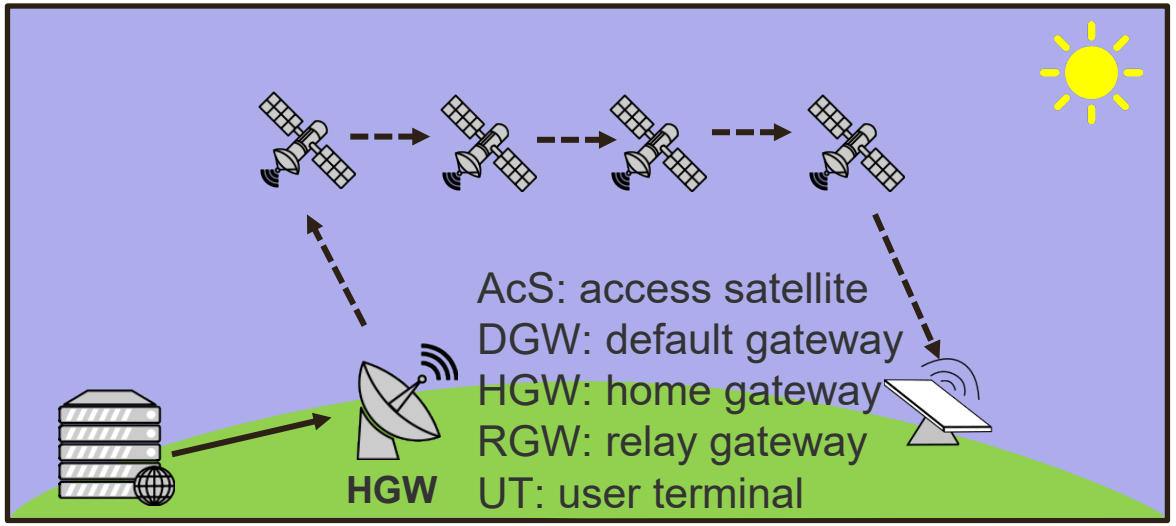
SR Forwarding Tables on Satellites

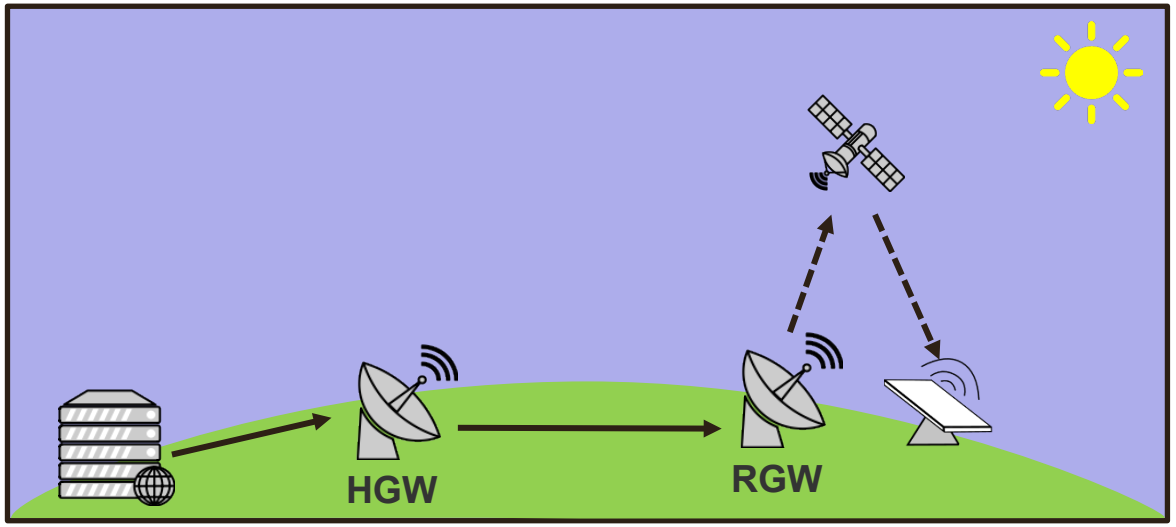
- Satellites connected to
  - Predecessor and successor within orbit (intra-orbit links)
  - One or two satellites in neighboring orbits (inter-orbit links)
- Neighborships relatively stable, but
  - Inter-orbit links may change near the poles
  - Satellites may fail
  - Satellites added to and removed from constellation
- Forwarding tables need updates
  - Can be configured ahead of time
  - Shadow forwarding entries activated on time
- Satellite controllers
  - Know entire constellation
  - E.g., control GWs (CGWs)



TE Use Case (1): Long Path HGW → UT

- Problem
  - Packets for UT delivered to HGW
  - **Default paths from HGW to AcS may be long**
  - Many satellite hops → long delay
- Solution
  - Access satellite may be faster reachable over another **relay GW (RGW)**
  - Tunnel pkt from HGW to RGW and forward it from there to AcS
  - Extended map‘n‘encaps info for UT in HGW

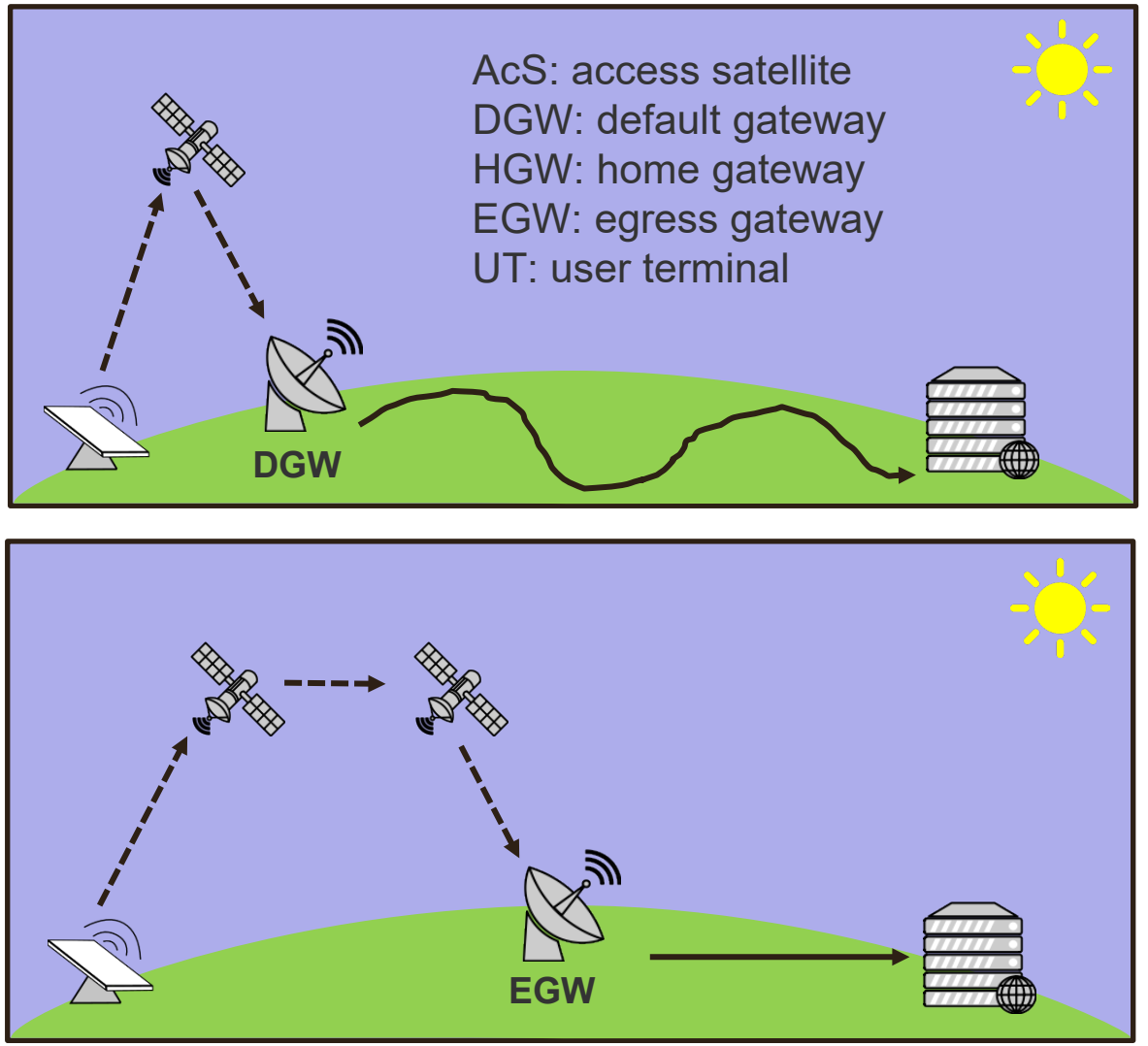




TE Use Case (2): Long Path DGW → Dest Prefix

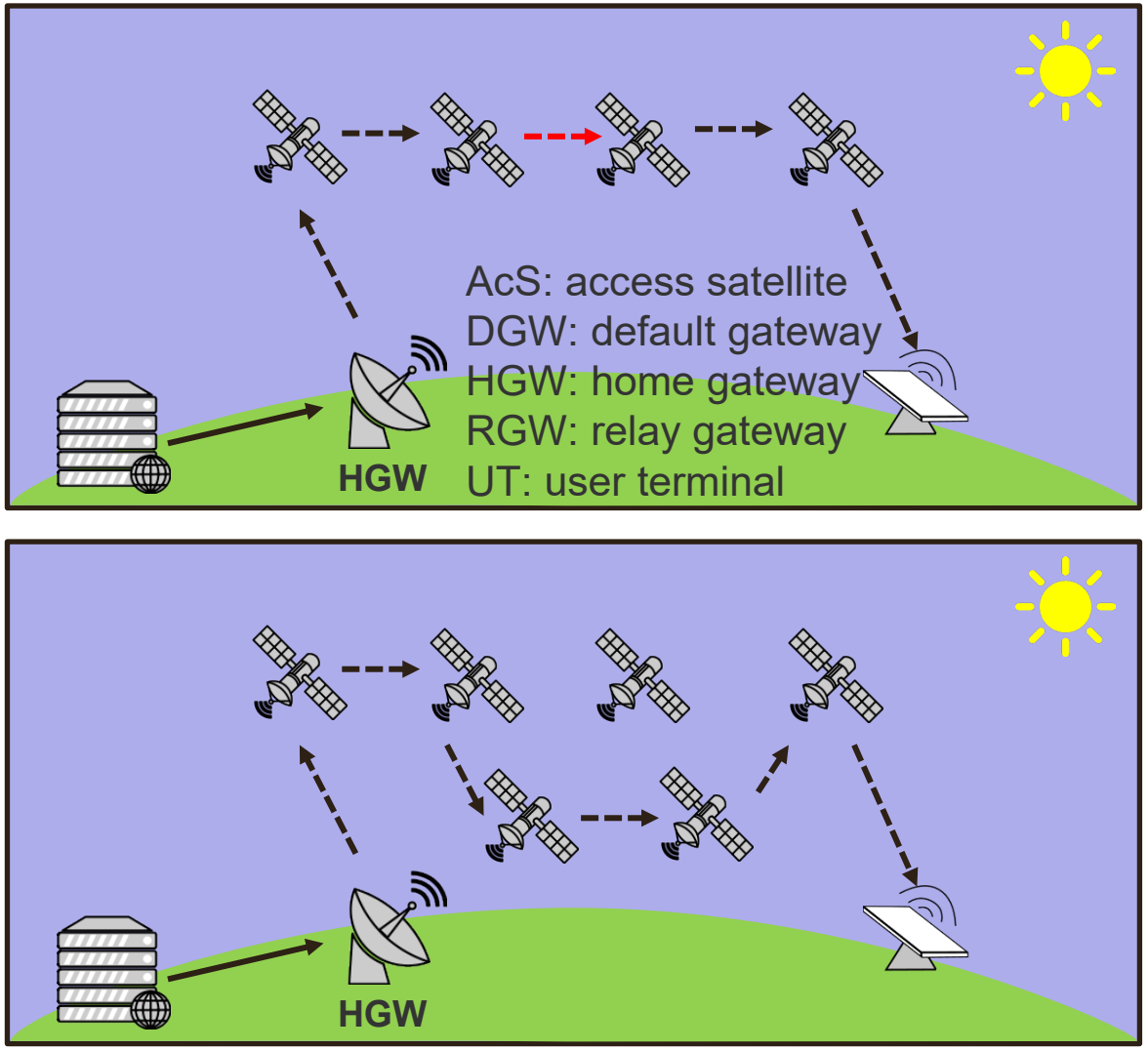
- Problem
  - Single default path on AcS for all traffic to DGW
  - **DGW may have only long path to certain destination IP prefix**

- Solution
  - Destination IP prefixes may be faster reachable over another **egress GW (EGW)**
  - Install map‘n‘encaps info on AcS: destination IP prefix → EGW



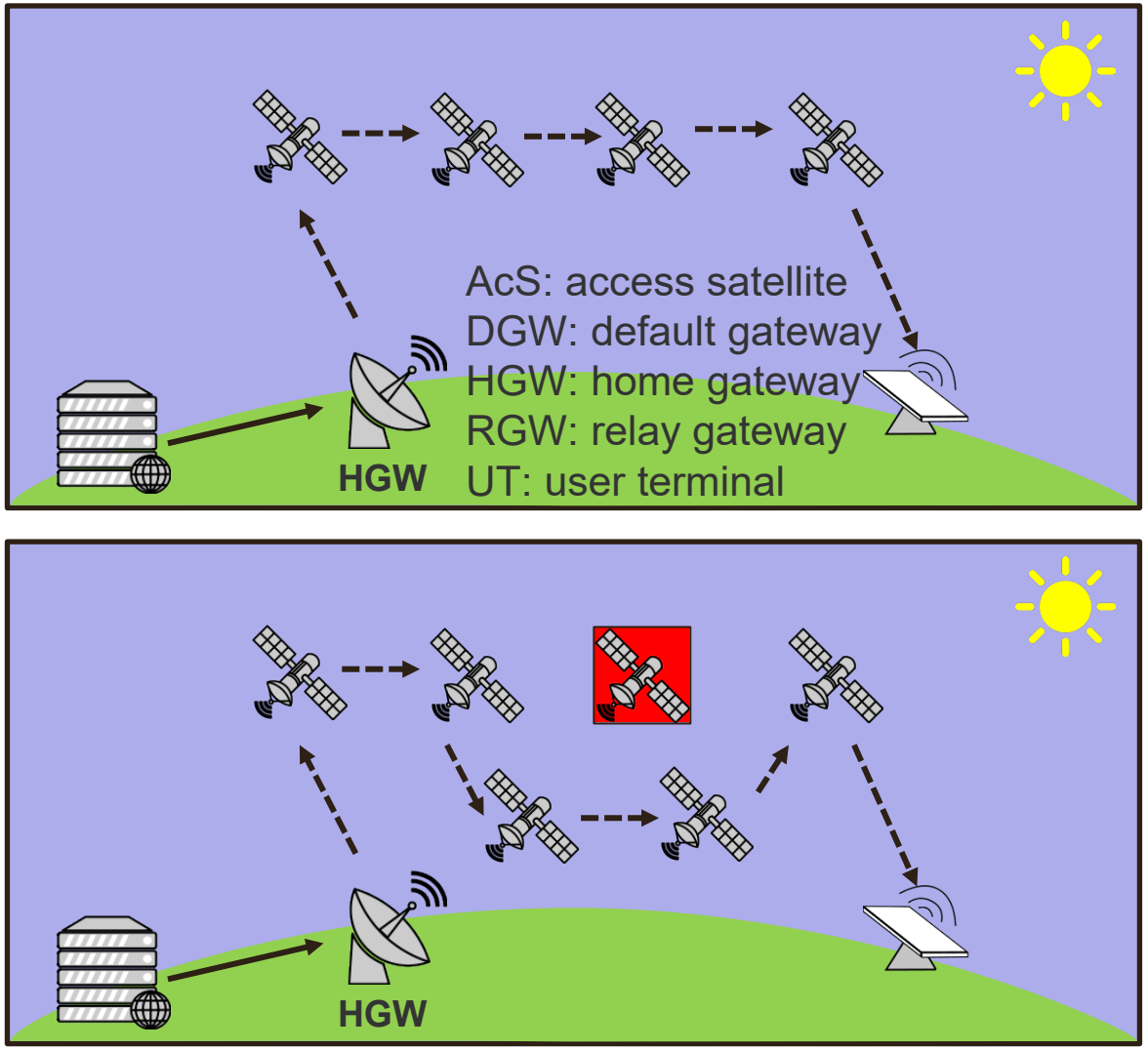
TE Use Case (3): Overloaded Inter-Satellite Link

- Problem
  - **Inter-satellite link may be overloaded**
  - Due to traffic concentration between hot spots
- Solution
  - **Steer traffic over other paths** towards destinations using SR



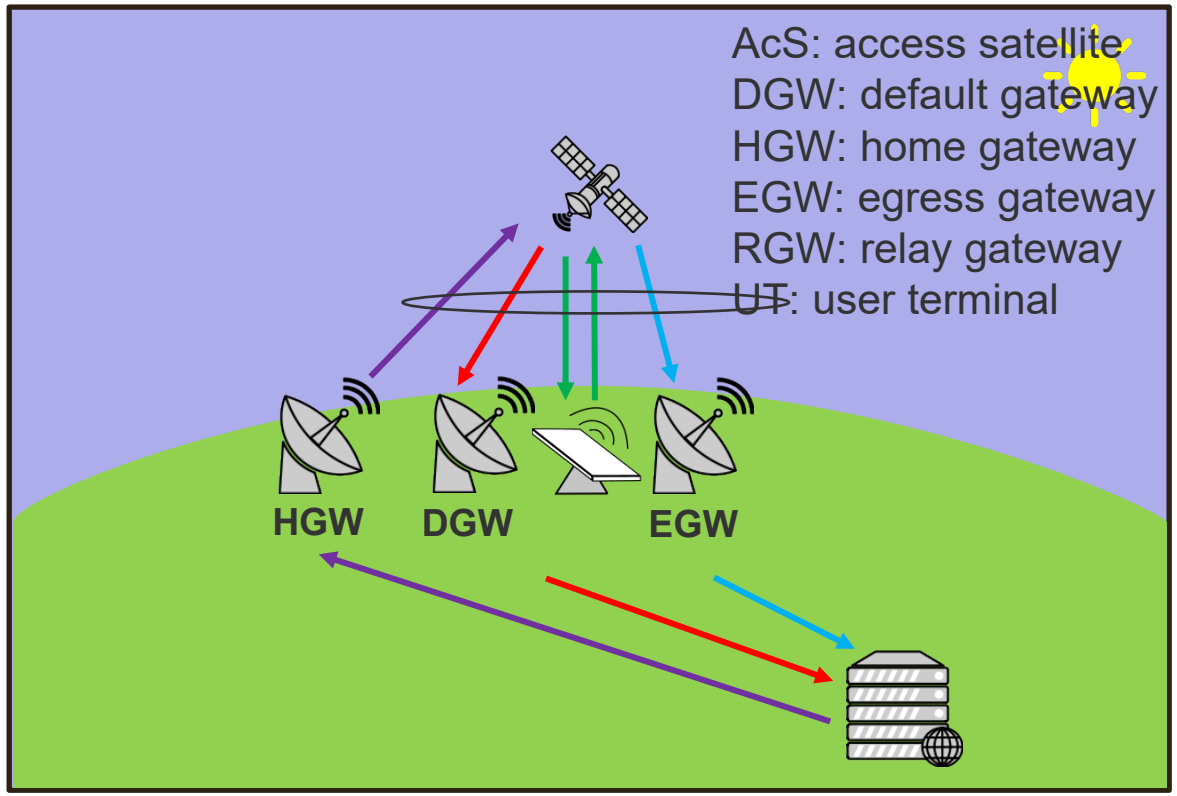
TE Use Case (4): Failed Satellite

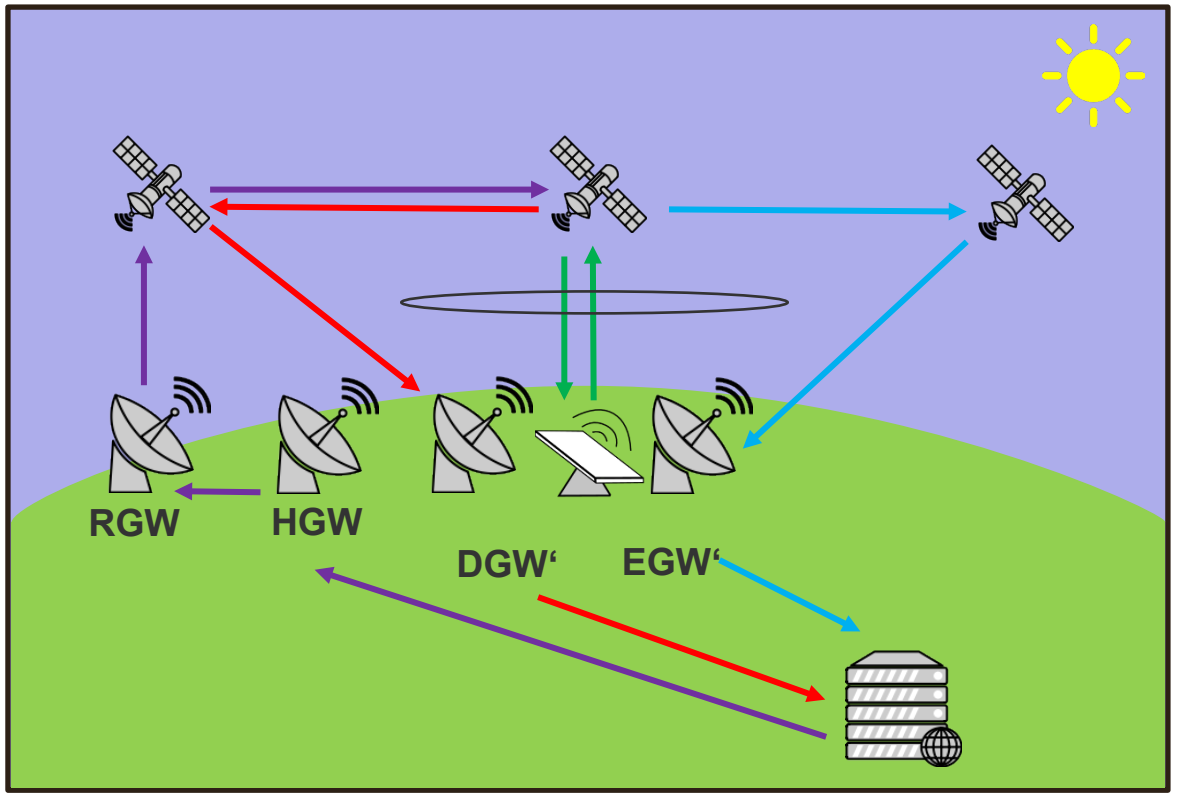
- Problem
  - **Satellite may fail**
  - May frequently due to high radiation in space
- Solution
  - **Fast reroute traffic over other paths** towards destinations using SR



TE Use Case (5): Overloaded Space-Ground Capacity

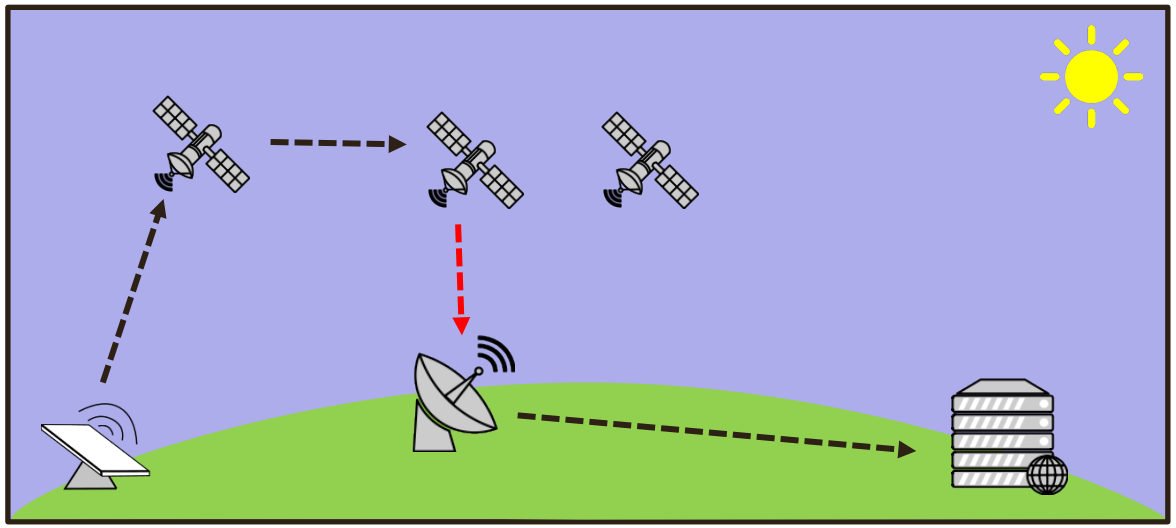
- Problem
  - **Satellite-ground capacity (feeder) may be overloaded**
- **Solution**
  - **Deviate traffic** from and to GW **via other GWs**
  - From HGW via RGW to AcS
  - From AcS to other DGW‘
  - From AcS to other EGW‘

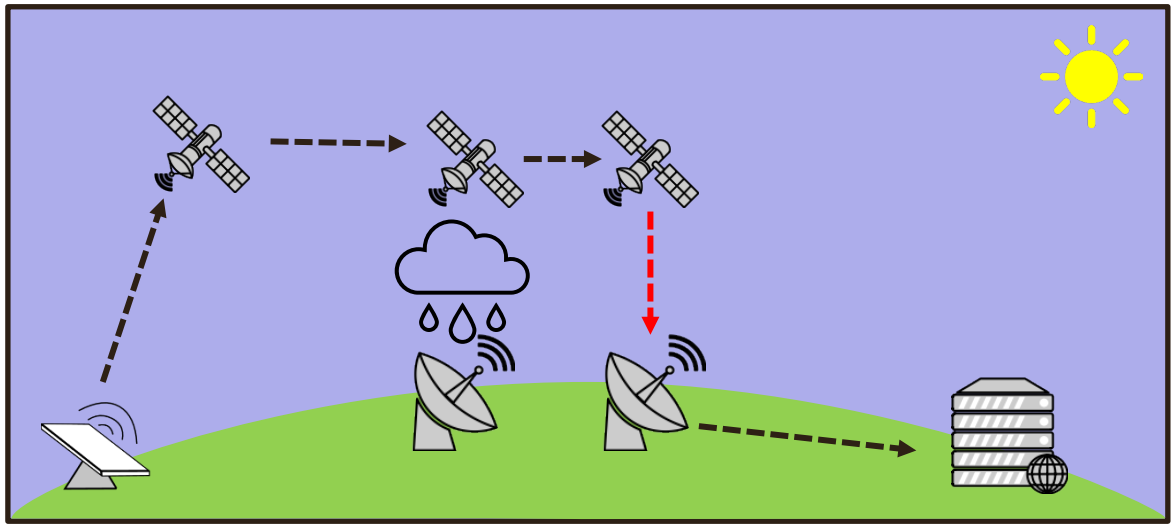




TE Use Case (6): Optical Feeders Fail

- Assumption
  - Optical feeders used for increased satellite-ground bandwidth in addition to RF links
- Problem
  - **Optical feeders fail due to cloudy weather**
- Solution
  - **Deviate traffic** for optical feeder **to other GWs** where weather is not cloudy
  - Same principle as in previous use case, but choice of alternate gateways depends on weather





Conclusion

- SDN approach
  - Data plane
    - Satellites using SR
  - Control plane (CGW, HGW) controls
    - SR forwarding tables and DGWs on satellites
    - Map‘n‘encaps tables in HGWs
- UTs not involved in routing
- TE use cases
  - For delay reduction, load balancing, offloading, fast rerouting
  - Use explicit paths or alternate GWs

- Future work
  - Simulate and protoype the control and data plane
  - Results and design alternatives may contribute to a SPACE RG to be