



Approaches for Efficient Global Ground Station Networks for Multiple Small Satellites

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Motivation

UWE-3 Launch im November 2013

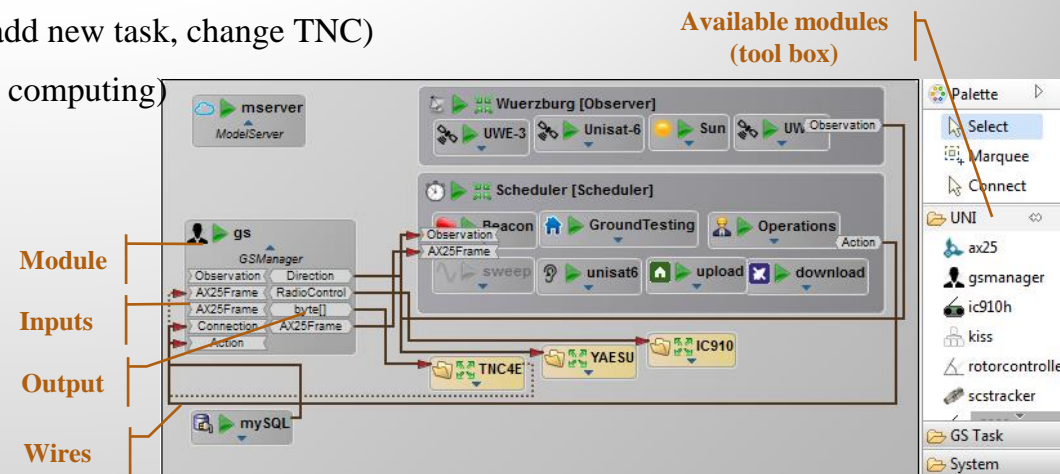
- 7 to 8 communication windows per day
- Ground Station stays inactive nearly 95% of the day
- No housekeeping data available if the satellite is out of range
- Usually different software components are used for
 - TNC control (data transmission)
 - Transceiver control (Doppler correction)
 - Propagation
 - Remote Control of the GS
 => different interfaces
- *Requirement:* remotely usable single software solution for GS hardware control, propagation and automated operations



Approach

- An OS-independent java solution was elaborated
- All components are implemented as *modules* with connectable ports for live data flow modifications
 - Modules for TNC, Radio and Antenna control
 - Module for orbit propagation of required satellites
 - Operations Scheduler for auto-activation of tasks depending on the defined constraints (target satellite, time, elevation etc.)
 - Task Modules for down- and upload, remote command execution, experiments etc.
 - Web-Server module for simple access via browser
 - Simple interface allows fast implementation of new modules
- Multiple clients can be connected to modify the running software using a GUI in real time
 - Add, remove or modify modules via preferences (e.g. add new task, change TNC)
 - Interconnect multiple framework instances (distributed computing)
 - Inject packets into desired ports, listen to outputs

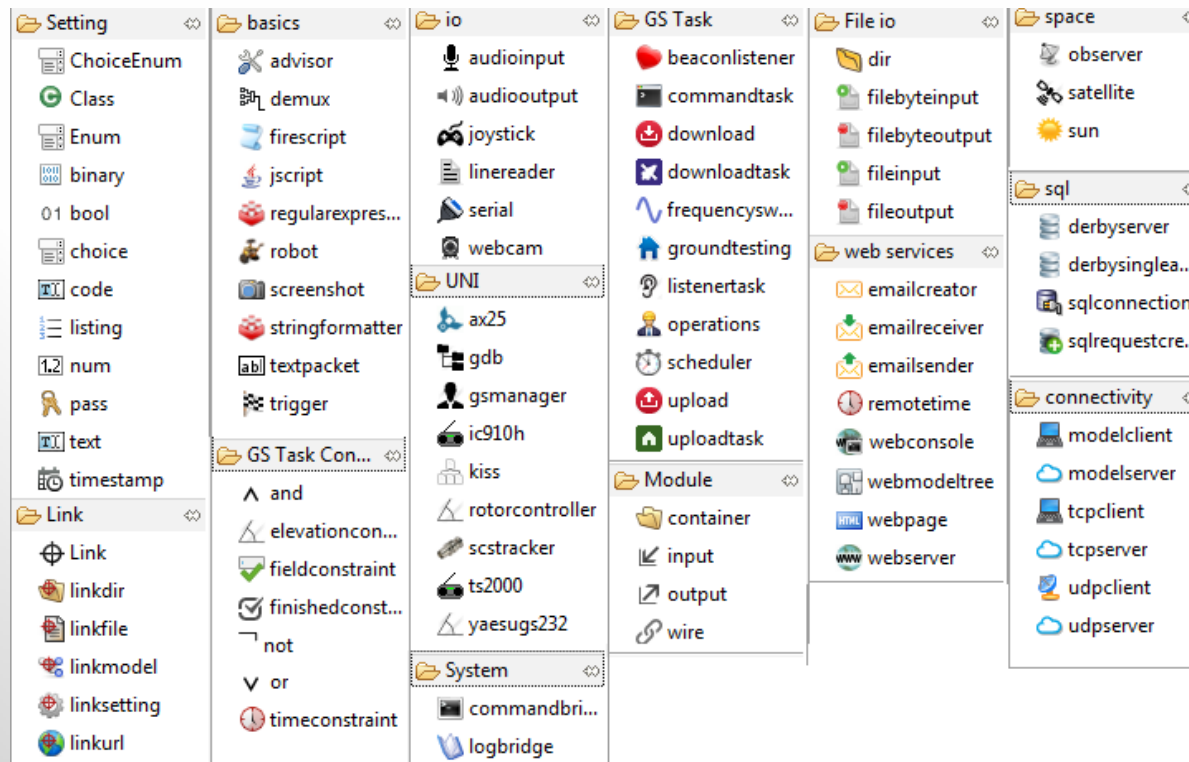
GS Network precursor



Framework for Intuitive and Rapid Software Evolution (FIRE)



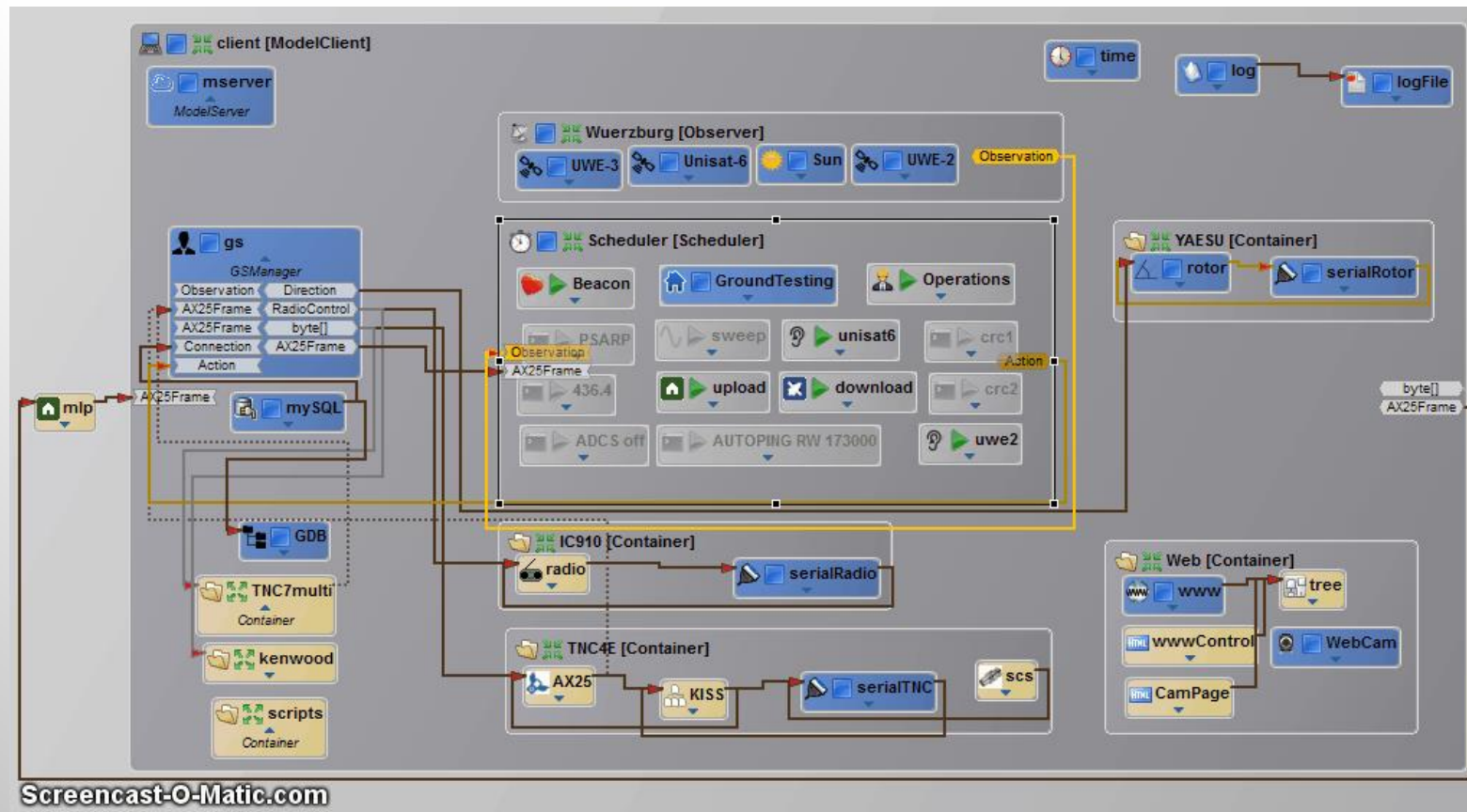
Toolbox





Approach

Dynamic data flow visualization





Web Interface

- The GS solution is independent of any external software and can be directly started
 - Many modules are already available
- The software is also fully accessible via the extensible web interface
 - All important values are displayed dynamically and can be set in real time
 - All modules and preferences can be accessed via the model tree
 - The interface can be made public in read-only mode

Web console | **GS Display** | **Fast GS Control**

The screenshot shows a web browser interface with a status bar at the top displaying '132.187.9.99:8080'. Below the status bar, there is a 'help' button and a 'SAT' indicator showing 'UWE-3'. The main display area features three gauges: 'RF%' at 29, 'Az' at 199, and 'El' at 179. Below the gauges is a 'Simple Control' section with buttons for 'Antenna' (left, right, up, down, stop) and input fields for 'Radio' (A: 437385000, B: 437385000) and 'TNC' (2nd UNISEC Global). At the bottom, there is a 'Log' section with a table of messages.

Time	Source	Message
2014/11/16 16:12:47	OverPassCalculator: OverPassCalculator (2041667448)	Calculate overpasses for UWE-3 within 2014/11/21 12:09:01 - 2014/11/21 [...]
2014/11/16 16:12:25	OverPassCalculator: OverPassCalculator (2041667448)	Overpass for UWE-2 calculated: 2014/11/21 15:11:08 - 2014/11/21 15:24: [...]
2014/11/16 14:34:18	GSManger: gs (125842246)	1 external packets injected (17 ms)
2014/11/16 14:34:06	GSManger: gs (125842246)	1 external packets injected (54 ms)

Software Model Tree

The screenshot shows a web browser interface with a status bar at the top displaying '132.187.9.99:8080'. Below the status bar, there is a 'Tree Model view' section. The tree view shows a hierarchical structure of elements, including 'root', 'YAESU', 'IC910', 'TNC4E', 'gs', 'kenwood', 'mserver', 'Scheduler', 'Wuerzburg', 'Coordinates', 'Radio', 'Sun', 'Unisat-6', 'UWE-2', 'UWE-3', 'ECI', 'Eclipse calculation', 'NORAD ID', 'Observation', 'Radio', 'Callsign', 'Downlink base freq [Hz]', 'Downlink modulation', 'Uplink base freq [Hz]', 'Uplink modulation', and 'TLE'. The 'Radio' element is selected, and its properties are displayed in a table below.

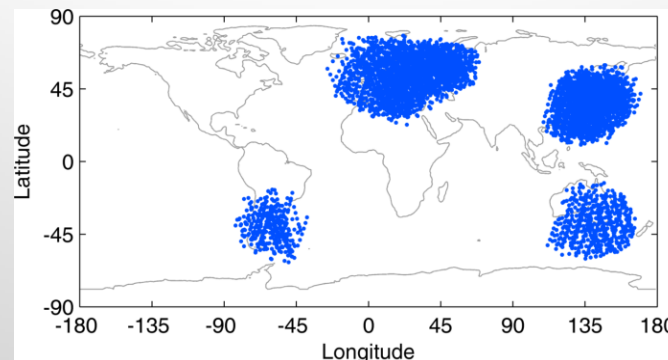
Element		Last Update
▼ root		
▶ YAESU		
▶ IC910		
▶ TNC4E		
▶ gs		
▶ kenwood		
▶ mserver		
▶ Scheduler		
▼ Wuerzburg		
▶ Coordinates		
▶ Radio		
▶ Sun		
▶ Unisat-6		
▶ UWE-2		
▼ UWE-3		
▶ ECI		
▶ Eclipse calculation		
▶ NORAD ID	39446	2014/07/16 13:35:26
▶ Observation		
▼ Radio		
▶ Callsign	DP0UWG	
▶ Downlink base freq [Hz]	437385000	2014/11/16 12:25:59
▶ Downlink modulation	GFSK_9600	
▶ Uplink base freq [Hz]	437385000	2014/11/16 12:26:24
▶ Uplink modulation	GFSK_9600	
▶ TLE	1 39446U 13	2014/11/10 20:04:19



Groundstation Sharing

1st stage: downlink only

- Web server interface for external packet injection (e.g. by radio amateurs, other universities)
- Operators can build up the server within < 1 hour
- Each GS tracks multiple satellites and forwards received packets
- Successfully proven with radio amateurs and GAUSS team (Unisat 6)
- Downlink capabilities beyond the reach of UWE-3
- Almost 70.000 external UWE-3 packets were received (until 2014/11/16)
- Over 4.700 packets were forwarded to other universities



Received UWE-3 packets



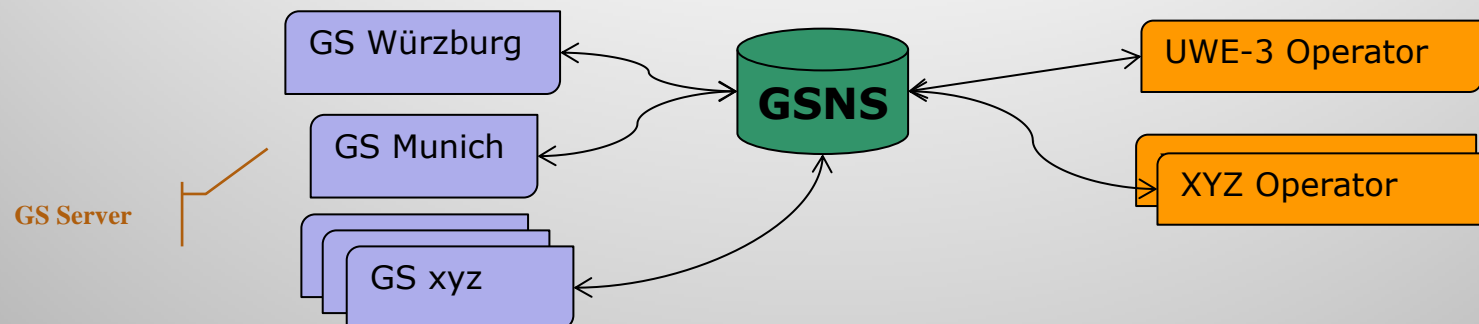
Groundstation Sharing

2nd stage: full access

- Using FIRE framework for GS handling and tracking/scheduling
- Remote ground stations can be used if currently not busy
- A field test is planned for December

In progress: Ground Station Network Server (GSN Server)

- Registering each GS instance on a central web server via web interface
- The server receives all required information and calculates free time slots
- GSN Server can be used as a logical ground station
 - The communication link is automatically forwarded to the appropriate GS
 - The higher the number of participants, the higher is the continuity of operations





Conclusion

- The Framework allows fast implementation of a GS software
- The toolbox gets permanently increased
- The Ground Station can be remotely handled via web interface
- The downlink-only GS sharing has been successfully tested and is still in use
- The full GS sharing will be tested in December
- The GSN Scheduler is in progress and will allow simple registration of new participants