Design elements for a Space Information Network Operating System

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ICSEA 2023, Valencia, Spain, October 2023
Presenter’s bio

Anders Fongen

- Associate Professor, Norwegian Defence University College
- Field of research: Distributed Systems, Networking security
- PhD in Distributed Systems, Univ. of Sunderland, UK, 2004
- Career history
  - 7 years in military engineering education (Associate Professor)
  - 10 years in defence research (Chief Scientist)
  - 8 years in civilian college (Associate Professor)
  - 11 years in oil industry
  - 6 years in electronics industry
Introduction

- The evolution of satellite communication?
  - Application services ("Cloud computing in space")
  - Higher system complexity (larger state space)
- What are the advantages?
  - Very low latency (as low as 3 ms)
  - Global coverage
- Interesting properties of a Low Earth Orbit (LEO) system:
  - Predictability of positions, links, routes and workload
  - Long idle periods (due to inhabited surface) mixed with traffic peaks
- Viewed as a problem of Distributed Computing
  - having a set of distinct properties
What is a SIN (Space Information Network)?

- A collection of communicating LEO satellites
- Able to serve terrestrial/airborne client
  - Communication services (e.g., IP transport, VoIP, Publish-Subscribe comm.)
  - Discovery Services (DNS, Service Brokering...)
  - Storage Services (Content Distribution Network, caching, session states)
  - Application Services (Collaborating editing, Situational awareness...)
- Resource constrained / disadvantaged
- Predictable workload and link availability
- “Mobile” system: Stationary clients, mobile infrastructure
- Rapid hand-over of client connection and client state
Population “heat map” from satellite footprint
Why is a distinct middleware/OS needed?

- A SIN is distributed and mobile in its very core
  - basic MW/OS services must be “Mobility-aware”
  - even server layers must conduct handovers
  - resource discovery, invocation and migration is a formidable problem
- Mobility and resource management affects many interfaces
  - container <-> component
  - client <-> container
  - container <-> resource management
- A set of software services should provide life-cycle management for components and containers (e.g. Docker)
Which are the distinguishing design factors?

● N-layer structure
  ○ Service providers need to be replicated
  ○ Loop-free graph (DAG)
  ○ Frequently rebuild of the invocation tree

● Handover operations
  ○ Surface nodes (client and service providers) are stationary
  ○ First tier of service providers must be visible to ground client (frequent handover)
  ○ Links between satellites may require handover if path becomes too long.

● Stateful migration
  ○ Make “session object” accessible for appointed node after migration
Which are the distinguishing...?

- Link and load predictability
  - Link availability and link budget can be estimated
  - Offered load can be estimated based on population statistics
  - Fewer discovery protocols needed

- Fail-over arrangement
  - Fail detection and fail-over should be conducted in the Management Plane, to relieve the clients from uncertain fail detection

- Security and trust management
  - “traditional” PKI certificate management has too high comm. requirements, authentication and authorization control should be done in one round trip
SIN-OS components

Figure 2. The components of a SIN-OS and their relations
Essential services in a SIN-OS

- **Non-volatile storage**
  - Files, OODBMS, RDMS, tuplespace. Distributed

- **Shared data segments**
  - Provides transaction protection, update ordering semantics, update notification ....
  - Clients must migrate in a synchronous manner

- **Cooperative caching**
  - Sharing immutable objects, coming from, e.g., lookup/discovery services

- **Session state objects**
  - Keeping session state variables accessible across handover operations

- **Discovery services**
  - Satellite positions can be predicted, but not the location of services

- **Certificate & key store**
  - Certificates likely to be different from X.509, with simpler validation methods

see: thinkmind.org
API collections

- **Client API**
  - Invokes services in satellite host SIN-OS (not service container)
  - Methods used for app *management*, others for *invocation*
  - `uploadApp`, `StartApp`, `ConnectApp`, `invokeService`, `requestHandover`

- **Container API**
  - Offered by the SIN-OS to the container
  - Resource allocation, life-cycle management
  - `loadApp`, `startApp`, `suspendApp`, `destroyApp`, `executeHandover`

- **Component API**
  - Access to SIN-OS services for storage, communication, synchronization etc.
  - Callback methods for life-cycle management
Conclusion

The problem: How could the characteristic problems in a SIN be solved by a well organized middleware/operating system?

- A SIN exhibits distinct problem due to the orbital cycle and predictable offered load (from surface clients)
- A SIN should provide a runtime environment for application components with proper separation and resource management, as well as the usual set of services for the execution (storage, communication, synchronization etc.)
- The application components are likely to be executed in a container environment, with a well defined API offered by the SIN-OS
- A suggested set of services and API have been presented in the paper.

Thank you for your attention, any questions?