Virtual Gateways in the DECOS Integrated Architecture

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Overview

- DECOS Integrated Architecture
- Virtual Networks
- Virtual Gateway Service
- Operation of Virtual Gateways
- Execution of Virtual Gateway Service
- Exemplary Application in Typical Automotive System
- Conclusion
Federated and Integrated Architectures

- Federated architectures provide each application subsystem with its own dedicated computer system
  - Natural separation of application subsystems
  - Complexity control
  - Fault isolation between computer system
  - Service optimization

- Integrated architectures support multiple application subsystems within a single distributed computer system
  - Reduced hardware cost
  - Dependability
  - Flexibility
DECOS Integrated Architecture

- Distributed Application Subsystems (DASs)
  - Nearly independent distributed subsystem
  - Exploit specific platform services
  - Infrastructure tailored to the needs of the DAS (e.g., TT or CAN communication)

Core Services (DAS-Indep.)
- C1 Predictable Message Transport
- C2 Fault-Tolerant Clock Synchronization
- C3 Strong Fault Isolation
- C4 Consistent Diagnosis of Failing Nodes

High-Level Services (DAS-Specific)
- Diagnostic Service
- Gateway Service
- Virtual Network Service
- Encapsulation Service

Time-Triggered Base Architecture

Hiding of implementation details from the application, thereby extending the range of implementation choices
Distributed Application Subsystem

- Consists of jobs
- Interconnected through a dedicated virtual network, which is an overlay network on top of the time-triggered core network
Virtual Gateways

- Virtual gateways support the interconnection of the virtual networks of two DASs
  - Improved quality of service
    - Example: Pre-crash systems
  - Exploit redundant sensors
    - Improve reliability
    - Reduce resource duplication
- Exemplary application: Sensor DAS
Hidden Virtual Gateway Services

Core Services (DAS-Indep.)
- Predictable Message Transport (C1)
- Fault-Tolerant Clock Synchronization (C2)
- Strong Fault Isolation (C3)
- Consistent Diagnosis of Failing Nodes (C4)

Virtual Network Infrastructure tailored to a DAS (e.g., TT)

Virtual Gateway Coupling of Virtual Networks

Safety-Critical Subsystem

Non-Safety-Critical Subsystem

Gateway Service
Virtual Network Service
Encapsulation Service

Time-Triggered Base Architecture

Hiding of implementation details from the application, thereby extending the range of implementation choices.

Core Services for Interfacing the Time-Triggered (TT) Physical Network of the Base Architecture
Role of a Virtual Gateway

- Property Transform.
- Semantic Properties
- Operational Properties
- Encapsulation
- Selective Redirection
- Complexity Control
- Error Containment
Operation of Virtual Gateways

- Each message is regarded as a compound structure
- Part of a message that is subject to selective redirection is denoted *convertible element*
- Received messages are dissected into convertible elements
- Sent messages are constructed out of convertible elements
- Convertible elements are stored in a real-time database

*) message buffer: queue for event information, state variable for state information
Gateway Repository for State and Event Information

- Real-time database
- Central data structure of a virtual gateway
- Temporally accurate convertible elements with state information
- Queuing of convertible elements event information in order to maintain state synchronization

<table>
<thead>
<tr>
<th>Information Semantics</th>
<th>Convertible Element Data</th>
<th>Meta Information</th>
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<tbody>
<tr>
<td>Convertible Element with State Semantics</td>
<td>![Mail icon]</td>
<td>$a_{acc}^1$ $b_{req}^1$ $t_{update}^1$</td>
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<tr>
<td>Convertible Element with State Semantics</td>
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<td>$a_{acc}^2$ $b_{req}^2$ $t_{update}^2$</td>
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<tr>
<td>Convertible Element with Event Semantics</td>
<td>![Mail icons]</td>
<td>$b_{req}^{k+1}$ request for convertible element instance</td>
</tr>
<tr>
<td>Convertible Element with Event Semantics</td>
<td>![Mail icons]</td>
<td>$b_{req}^{k+2}$ request for convertible element instance</td>
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Interaction with Virtual Networks

- Gateway sends and receives messages at two virtual networks.
- Link specification for each virtual network consists of:
  1. Syntactic specification defines structure of message and is used to parse incoming messages / construct outgoing messages.
  2. Temporal specification defines the interaction protocol.
  3. Transfer semantics for conversion between event and state information:
     - State information through accumulation of event information.
     - Event information derived from successive state information values.
Update of Gateway Repository: Sparse Time Base

- In abstract system theory (Mesarovic, 1989), the notion of state is introduced in order to separate the past from the future.
- Sparse time model: partitioning of the continuum of time (durations of action and silence).
- Action lattice.
- Interval of silence:
  - Interval when the distributed state of the system is defined.

![Diagram showing past, future, and state intervals]
Update of Gateway Repository (2)

- Activity Intervals: update of *port state* through the gateway
- Silence Intervals: prevents concurrency with the update of the port state through the virtual networks.

<table>
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<tr>
<th>Gateway Execution</th>
<th>Silence</th>
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- Activity Intervals: update of *port state* through the communication system (message receptions and message transmission via virtual networks)
- Silence Intervals: globally consistent input is provided via the port state to the gateway

$n$ Ticks

t
Conclusion

- Virtual gateways are a key mechanism for combining advantages of federated and integrated architecture
  - Functionally federated, physically integrated
  - Encapsulation of DAS with dedicated virtual networks
- Virtual gateways for the coupling of virtual networks
  - Exploit redundancy to reduce cost and improve reliability
  - Improve quality of service
- Virtual gateways as an architectural service
  - Generic service that is parameterized by application requirements in order to simplify application development
  - Selective redirection of information between virtual networks through controlled import and export
  - Property transformations
- Update of real-time database on global sparse time base