Developing Distributed RT Systems Using OS System-Hiding Frameworks

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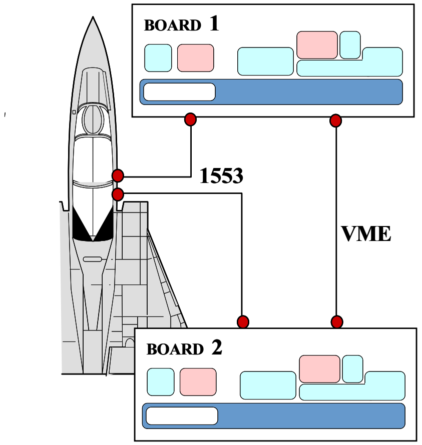
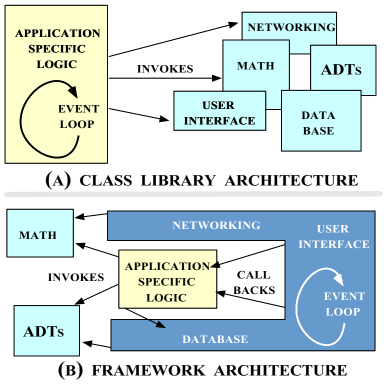
Motivation: the Distributed RT Communication Software Crisis



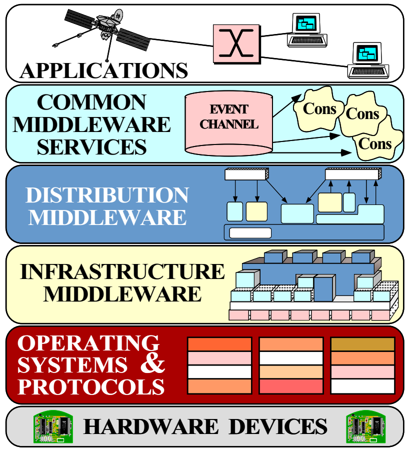
- **Symptoms**
  - Hardware gets smaller, faster, cheaper
  - Software gets larger, slower, more expensive
- **Culprits**
  - *Accidental* and *inherent* complexity
- **Solutions**
  - Frameworks, components, and patterns

Techniques for Improving Software Quality and Productivity



- **Proven solutions**
  - *Components*
    - ∗ Self-contained, "pluggable" ADTs
  - *Frameworks*
    - ∗ Reusable, "semi-complete" applications
  - *Patterns*
    - ∗ Problem/solution pairs in a context
  - *Architecture*
    - ∗ Families of related patterns and components

Roadmap to Levels of Middleware Abstraction

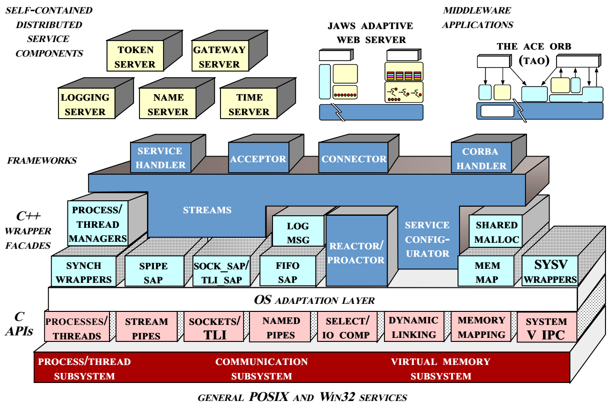


- **Observations**
  - Historically, apps built directly atop OS
  - Today, more and more apps built atop *middleware*
  - Middleware has several layers
- **General R&D challenges**
  - Performance optimizations
  - Quality of Service (QoS)
  - Software architecture & patterns

Why We Need Communication Middleware

- **System call-level programming is wrong abstraction for application developers**
  - *Too low-level* → error codes, endless reinvention
  - *Error-prone* → HANDLEs lack type-safety, thread cancellation woes
  - *Mechanisms do not scale* → RTOS TSS
  - *Steep learning curve* → Win32 Named Pipes
  - *Non-portable* → socket bugs
  - *Inefficient* → *i.e.*, tedious for humans
- **GUI frameworks are inadequate for communication software**
  - *Inefficient* → excessive use of virtual methods
  - *Lack of features* → minimal threading and synchronization mechanisms, no network services

The ADAPTIVE Communication Environment (ACE)



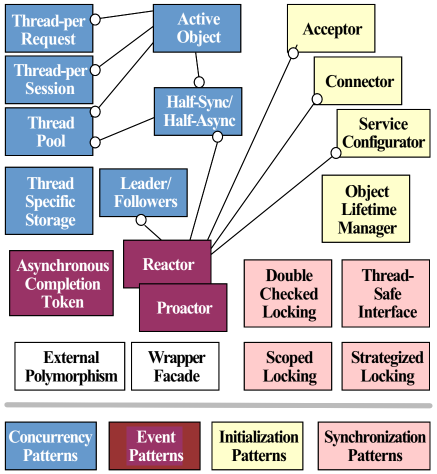
http://www.cs.wustl.edu/∼schmidt/ACE.html

- **ACE Overview**
  - A concurrent OO networking framework
  - Available in C++ and Java
  - Ported to VxWorks, POSIX, and Win32
- **Related work**
  - x-Kernel
  - SysV STREAMS

ACE Statistics

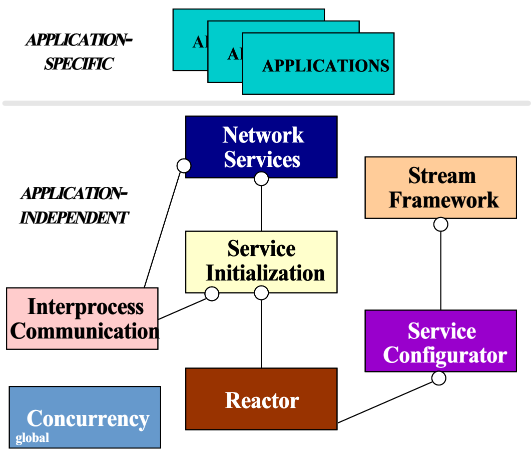
- ACE contain > 200,000 lines of C++
  - Over 30 person-years of effort
- Ported to UNIX, Win32, MVS, and embedded platforms
  - *e.g.*, VxWorks, LynxOS, Chorus, pSoS, QNX
- Large user community
  - www.cs.wustl.edu/∼schmidt/ACE-users.html
- Currently used by dozens of companies
  - Boeing, Cisco, Ericsson, Kodak, Lockheed, Lucent, Motorola, Nokia, Nortel, Raytheon, SAIC, Siemens, StorTek, etc.
- Supported commercially
  - www.riverace.com

Patterns for Communication Middleware



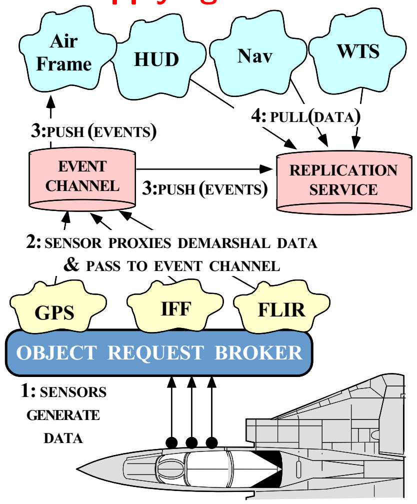
- **Observation**
  - *Failures rarely result from unknown scientific principles, but from failing to apply proven engineering practices and patterns*
- **Benefits of Patterns**
  - Facilitate design reuse
  - Preserve crucial design information
  - Guide design choices

Use-cases for ACE and TAO



- **Domains**
  - Real-time avionics
  - Distributed interactive simulations
  - Satellite communication
  - Network management
  - Medical imaging
  - Multimedia services

Applying ACE to Real-time Avionics

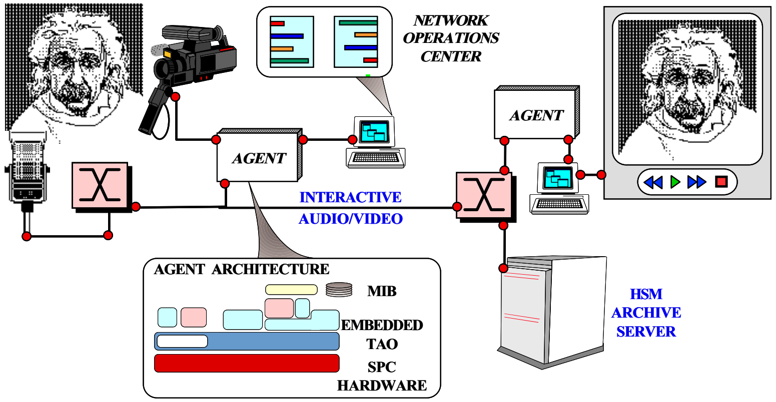


Domain Challenges

- Deterministic & statistical real-time deadlines
- Periodic & aperiodic processing
- COTS and open systems
- Reusable components
- Support platform upgrades

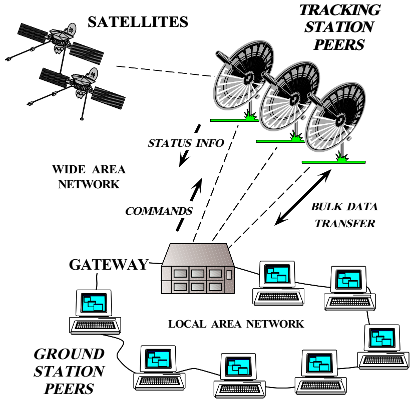
www.cs.wustl.edu/~schmidt/TAO-boeing.html

Applying ACE to Distributed Interactive Simulations



www.cs.wustl.edu/~schmidt/Words99.ps.gz

Applying ACE to Satellite Communication Systems



- **Domain Challenges**
  - Long latency satellite links
  - High reliability
  - Prioritization

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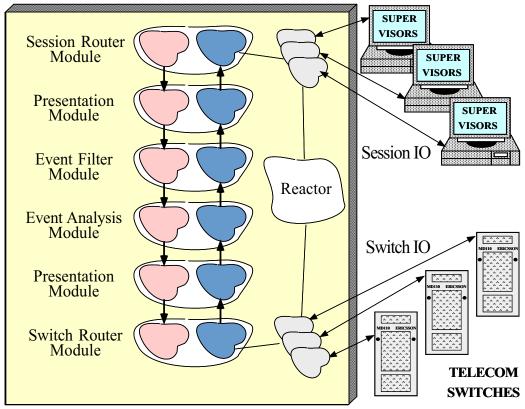
Applying ACE to Network Management



www.cs.wustl.edu/~schmidt/DSEJ-94.ps.gz

- **Domain Challenges**
  - Low latency
  - Multi-platform
  - Family of related services

Lessons Learned Building ACE

- **Be patient**
  - Good components, frameworks, and software architectures take time to develop
- **Reuse-in-the-large works best when:**
  1. The marketplace is competitive
  2. The domain is complex
  3. Skilled middleware developers
  4. Supportive corporate culture
  5. "Reuse magnets" exist
  6. Open source development models
- **The best components come from solving real problems**
  - Keep feedback loops tight to avoid "runaway" reuse efforts
- **Produce reusable components by generalizing from working applications**
  - *i.e.*, don't build components in isolation

Concluding Remarks

- Developers of real-time communication software confront recurring challenges that are largely application-independent
  - *e.g.*, service initialization and distribution, error handling, flow control, event demultiplexing, concurrency control, synchronization, scheduling
- Programming directly to the underlying OS APIs is tedious, error-prone, and non-portable
- Successful developers resolve these challenges by applying appropriate *design patterns* to create communication *frameworks*
- Application *frameworks* are an effective way to achieve broad reuse of software

Obtaining ACE

- All source code for ACE is freely available
  - www.cs.wustl.edu/~schmidt/ACE.html
- Mailing lists
  - ace-users@cs.wustl.edu
  - ace-users-request@cs.wustl.edu
  - ace-announce@cs.wustl.edu
  - ace-announce-request@cs.wustl.edu
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  - comp.soft-sys.ace
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  - www.riverace.com