Using the ACE Framework and Patterns to Develop OO Communication Software

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Sponsors

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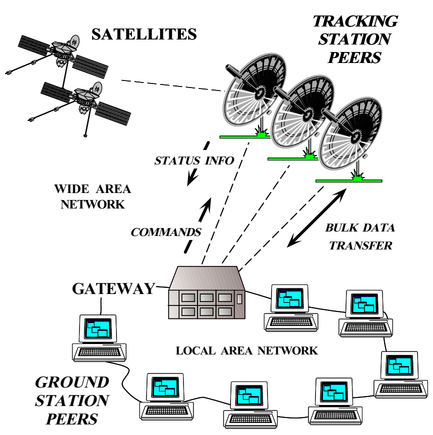
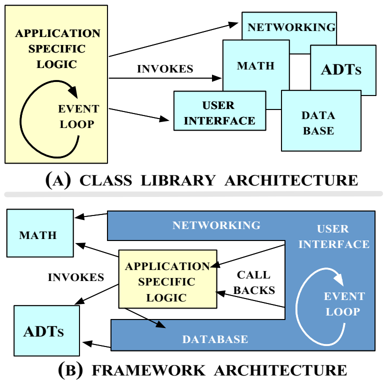
Motivation: the Distributed Software Crisis



- **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

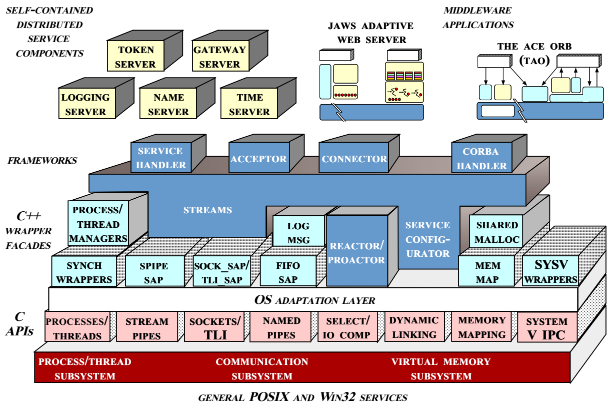


- **Proven solutions**
  - *Components*
    - Self-contained, "pluggable" ADTs
  - *Frameworks*
    - Reusable, "semi-complete" applications
  - *Patterns*
    - Problem/solution pairs in a context
  - *Architecture*
    - Families of related patterns and components

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* → Win32 TLS
  - *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)



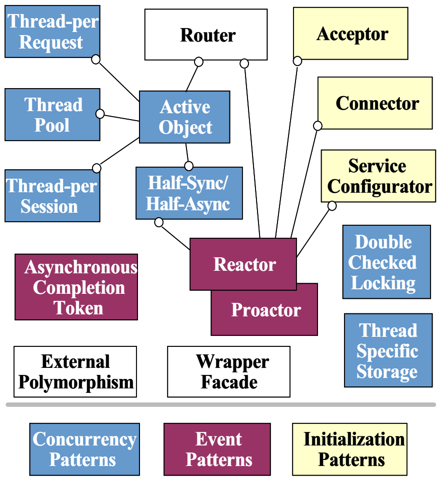
http://www.cs.wustl.edu/~schmidt/ACE.html

- **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

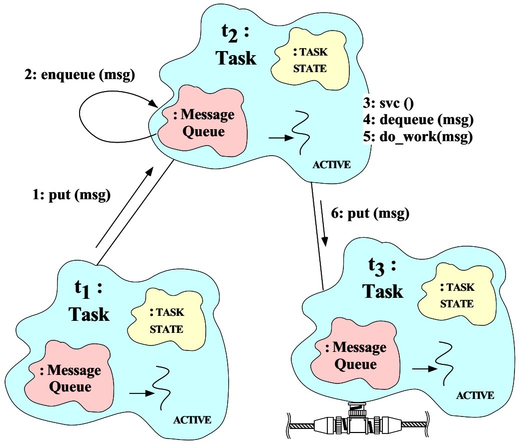
- ACE contain > 185,000 lines of C++
  - Over 20 person-years of effort
- Ported to UNIX, Win32, MVS, and embedded platforms
  - *e.g.*, VxWorks, LynxOS, Chorus
- Large user community
  - www.cs.wustl.edu/~schmidt/ACE-users.html
- Currently used by dozens of companies
  - Bellcore, Boeing, Ericsson, Kodak, Lockheed, Lucent, Motorola, Nokia, SAIC, Siemens, StorTek, etc.
- Supported commercially
  - www.riverace.com

Patterns for Communication Middleware



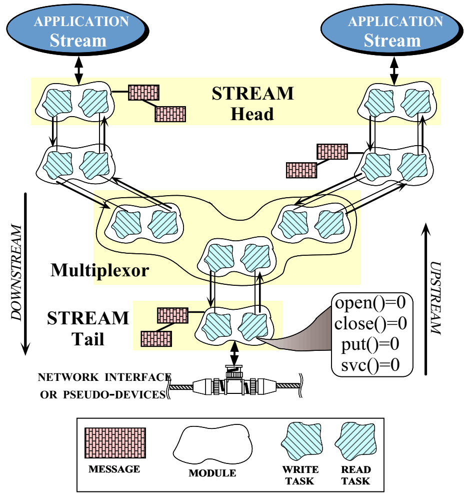
- **Observation**
  - *Failures rarely result from unknown scientific principles, but from failing to apply proven engineering practices and patterns*
- **Benefits of Patterns**
  - Facilitate design reuse
  - Preserve crucial design information
  - Guide design choices

Active Objects with ACE Tasks



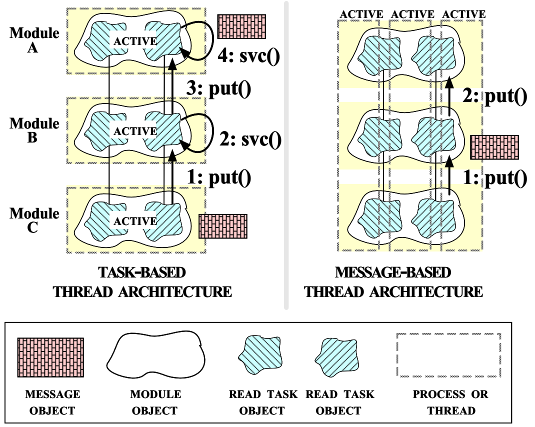
- **ACE Task Features**
  - Queueing
  - Event demultiplexing
  - Concurrency
  - Dynamic linking

The ACE Stream Class Category



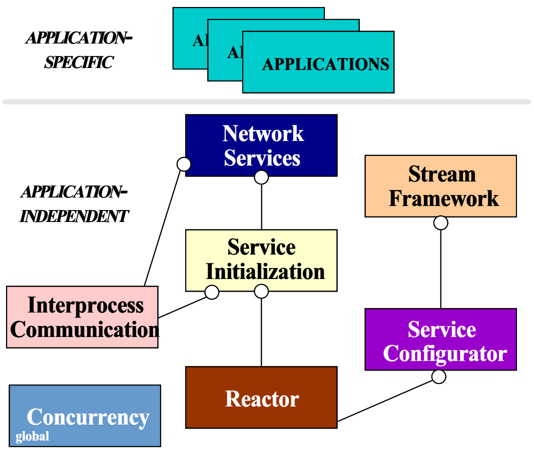
- ACE Stream Features
  - Layered service composition
  - Synchronous and asynchronous messaging
  - Dynamic configuration

Alternative Concurrency Models



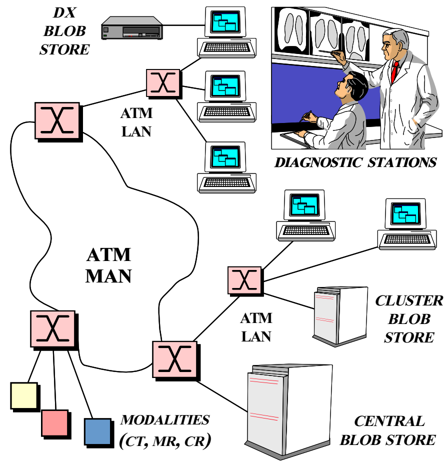
- Message-based Evaluation
  - Low overhead
  - Harder to program
- Task-based Features
  - Higher overhead
  - Easier to program

Use-cases for ACE



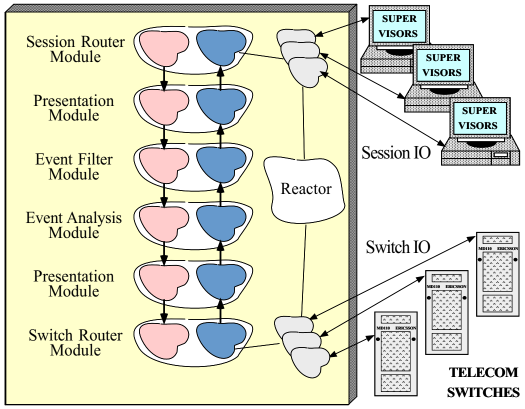
- Domains
  - Medical imaging
  - Network management
  - Wireless communications
  - Real-time avionics
  - Multimedia services

Applying ACE to Medical Imaging



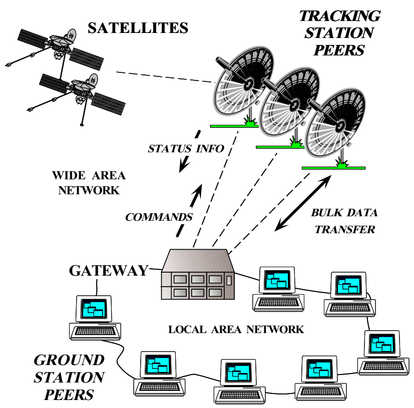
- Domain Challenges
  - Large volume of "Blob" data
    - ∗ *e.g.*, 10 to 40 Mbps
  - "Lossy compression" isn't viable
  - Prioritization of requests
- ~schmidt/COOTS-96.ps.gz
- ~schmidt/av.ps.gz

Applying ACE to Network Management



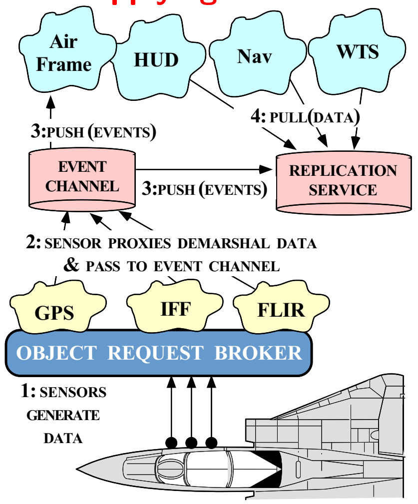
- **Domain Challenges**
  - Low latency
  - Multi-platform
  - Family of related services
  - ~schmidt/DSEJ-94.ps.gz

Applying ACE to Global PCS



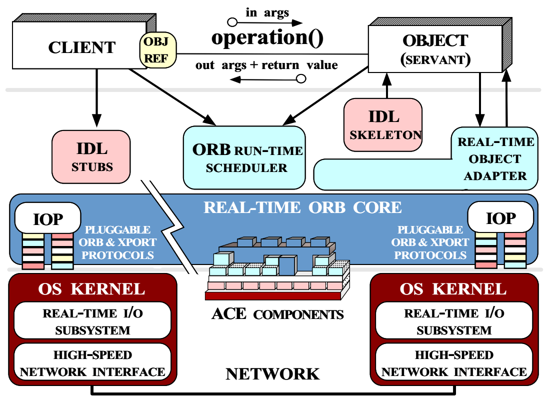
- **Domain Challenges**
  - Long latency satellite links
  - High reliability
  - Prioritization
  - ~schmidt/TAPOS-95.ps.gz

Applying ACE to Real-time Avionics



- **Domain Challenges**
  - Real-time periodic processing
  - Complex dependencies
  - Very low latency
  - ~schmidt/JSAC-98.ps.gz

The ACE ORB (TAO)

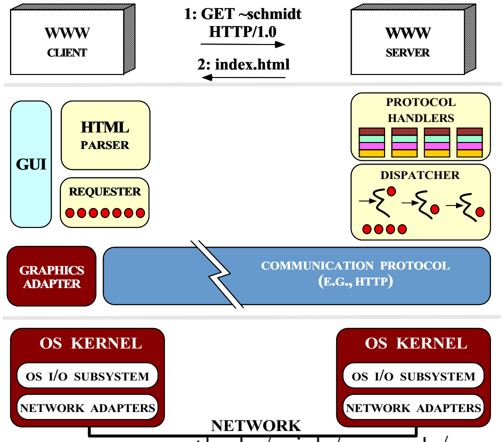


- **TAO Overview**
  - High-performance, real-time ORB
    - ∗ Networking and avionics focus
  - Leverages ACE
    - ∗ Runs on VxWorks, POSIX, and Win32
- ~schmidt/TAO.html

TAO Statistics

- Over 15 person-years of effort
  - TAO contains > 350,000 lines of C++
- Ported to UNIX, Win32, MVS, and RTOS platforms
  - *e.g.*, VxWorks, LynxOS, Chorus
- Large user community
  - www.cs.wustl.edu/~schmidt/TAO-users.html
- Currently used by dozens of companies
  - BBN, Boeing, Lucent, Motorola, Raytheon, SAIC, Siemens, etc.
- Supported commercially
  - www.ociweb.com

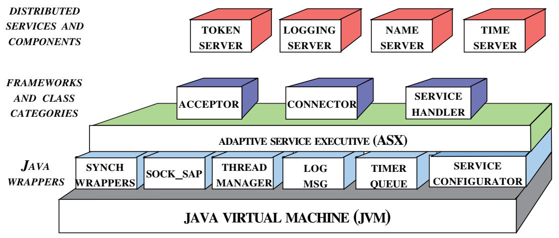
JAWS Adaptive Web Server



www.cs.wustl.edu/~jxh/research/

- **JAWS Overview**
  - A high-performance Web server
    - ∗ Flexible concurrency and dispatching mechanisms
  - Leverages the ACE framework
    - ∗ Ported to most OS platforms
  - Used commercially by Entera
    - ∗ www.entera.com

Java ACE



~schmidt/JACE.html
~schmidt/MedJava.ps.gz
~schmidt/C++2java.html

- **Java ACE Overview**
  - A version of ACE written in Java
  - Used for medical imaging prototype

Lessons Learned Building ACE

- Good components, frameworks, and software architectures take time to develop
- Reuse-in-the-large works best when:
  - The marketplace is competitive
  - The domain is complex
  - Building middleware in-house costs too much
  - Corporate culture is supportive
- Produce reusable components by generalizing from working applications
  - *i.e.*, don't build components in isolation
- The best components (and systems research) come from solving real problems

Concluding Remarks

- Developers of communication software confront recurring challenges that are largely application-independent
  - *e.g.*, service initialization and distribution, error handling, flow control, event demultiplexing, concurrency control
- 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

- ACE is an OO framework that reifies key communication software patterns
- 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
- Newsgroup
  - comp.soft-sys.ace