Developing Distributed Real-time Systems Using OS System-Hiding Frameworks

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Motivation: the Distributed Real-time 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/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

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
- Supported commercially
  - www.riverace.com

Related work

- x-Kernel
- SysV STREAMS
### 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

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

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

### Applying ACE to Satellite Communication Systems

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

www.cs.wustl.edu/~schmidt/TAPOS-95.ps.gz
Applying ACE to Network Management

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

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
- Newsgroup
  - comp.soft-sys.ace
- Commercial support
  - www.riverace.com

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

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- Commercial support
  - www.riverace.com
**Next Steps: POSIX ACE (PACE)**

- **PACE (POSIX ACE)** is a bottom-up rework of ACE
  - OS adaptation layer
    - Strict POSIX.1 interface
    - C, not C++
    - Partitioned, not monolithic
      - Corresponding to POSIX.1 sections
      - Adds configurability, reduces learning curve
  - The rest of ACE will ultimately migrate to PACE
    - *i.e.*, Utilities, Logging, Threads, Event Demultiplexing and Handling, Sockets, IPC, Service Configuration, Streams, and Memory Management
  - Then, TAO will migrate to PACE

**PACE: Footprint Reduction**

- Interface stability vs. small footprint
  - PACE will not necessarily be backward compatible with ACE
- General purpose middleware vs. small footprint
  - Revisit some “forgotten” techniques, such as a separate file for each method, to minimize linking of unused code

**PACE: Miscellaneous**

- Avoid static objects that require construction/destruction, multiple inheritance, *etc.*
- Strict component hierarchy, to support subsetting
- No mandatory exception handling
- For rapid access to non-POSIX ACE platforms, PACE will be ported to ACE’s OS adaptation layer (*ACE_OS*)

**PACE Challenges**

- How do we decide what to exclude from ACE?
  - Knowledge of implementation concessions provides candidates, such as backward compatibility for, *e.g.*, Reactor and static objects
  - Must support TAO
- How do we maintain two (three, with JavaACE) versions?
  - Initially, host PACE on ACE to rapidly provide support for non-POSIX platforms
  - Long term, provide adapter from PACE to ACE to support existing ACE applications