Reducing Component Contract Overhead by Offloading Enforcement

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Outline

Benefits of Contracts

Executable component contracts have several advantages:

- Improve application quality, by promoting safer reuse
- Provide a better description of a component's functionality than plain IDL

To be fully effective, contracts should be enforced even after the application is deployed (in production scenarios)

- Contract excercised through a variety of real parameters

Contracts in Common Component Architecture (CCA)

Example

```
bool vuIsZero(in array<double> u, in double tol)
  require
    not_null : u != null;
    u_is_1d : dimen(u) == 1;
    non_negative_tolerance: tol >= 0.0;
  ensure
    no_side_effects : is pure;
```

- SIDL extensions for expressing contracts as method preconditions, postconditions and class invariants
- Support for both simple and complex contracts
  - Logical operations (and, or, implies, if and only if, etc.)
  - Contracts may contain function calls
    - Nested functions' contracts (if they exist) are turned off
  - Predefined functions also exist (e.g. max, sum, min, etc.)

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Is is worthwhile to postpone the enforcemenet of contracts to when the system is less busy in order to reduce their performance impact?

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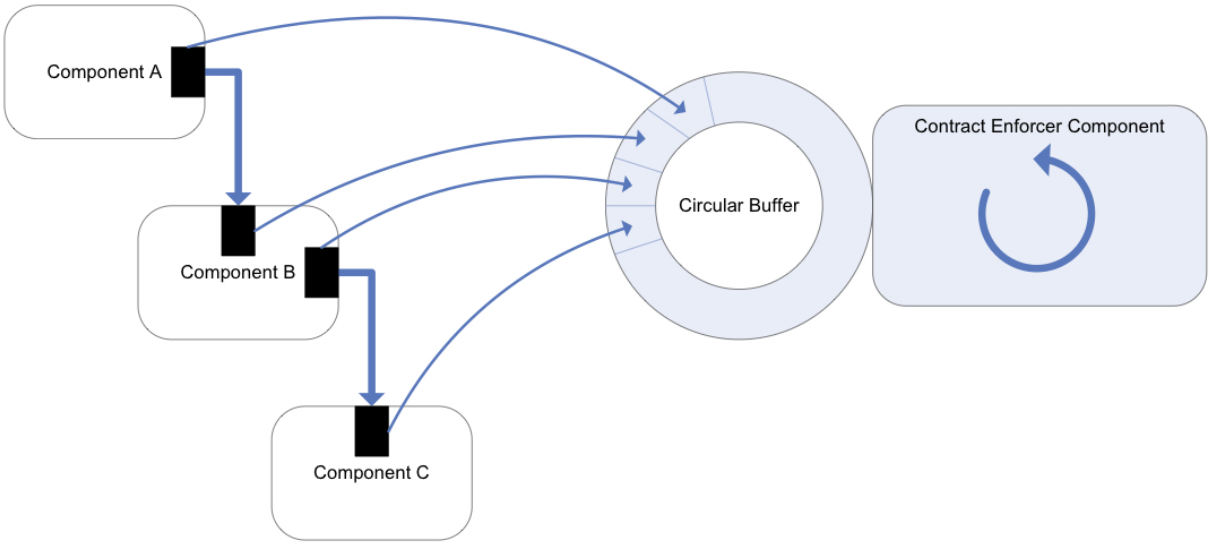
Answer

In some cases, yes.

- More detail follows. . .

Design of Contract Offloading System



- Save a copy of the data needed to enforce the contract and some small meta data
  - A circular buffer caps the memory expenditure
- A low priority thread in a ContractEnforcer component enforces the contracts
  - The ContractEnforcer may exist on a separate computational resource

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- If the contract is eventually enforced...
  - ...and if there was a violation then the application may have produced incorrect results or spent a little bit extra time computing
    - User is informed of contract violation, even if application has finished
  - ...and if there was no violation then no harm no foul

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  - This may violate user expectations
  - Unlikely to occur in many executions or to the same contract
  - Perhaps a reasonable price to pay for runtime contracts in HPC

When to Offload?

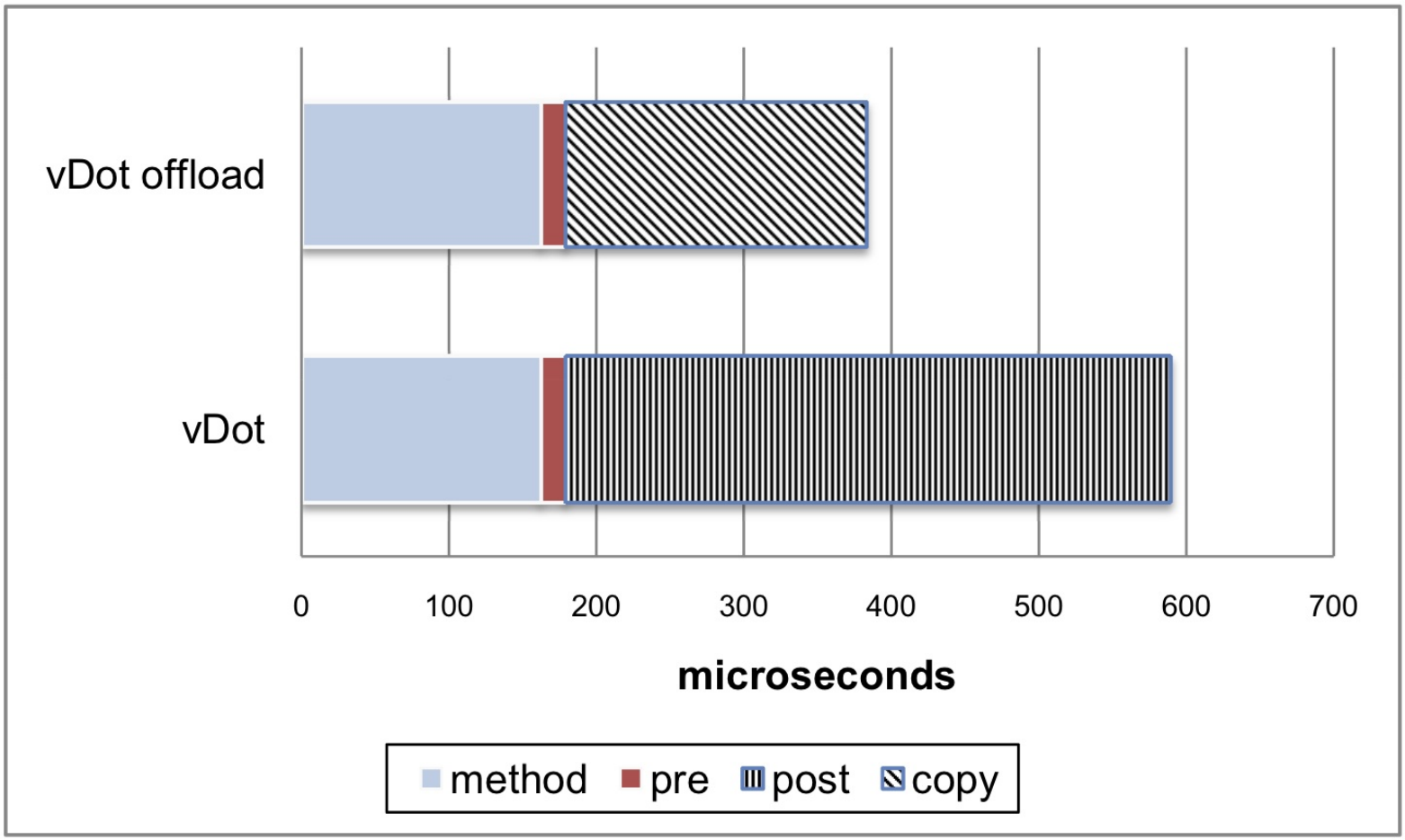
- The cost of offloading the contracts is a copy of the contract's data
- Some contracts are more expensive to copy than to enforce in place
  - Do not offload computationally cheap (per data unit) contracts
- Determine the contracts that have significant computational complexity per data unit
  - Prefer offloading complex contracts for later enforcement

Experiment

- Tested contract offloading using Babel on an interface performing a set of vector operations
- Measured contract offloading to a ContractEnforcer component in the same address space
- Confirmed suspicion that offloading is appropriate for certain complex contracts, where computational complexity is linear or more

The *vDot* Method

```
double vDot(in array<double> u, in array<double> v,
            in double tol)
  require
    not_null_u: u != null;
    u_is_1d : dimen(u) == 1;
    not_null_v: v != null;
    v_is_1d : dimen(v) == 1;
    same_size:  size(u) == size(v);
    non_negative_tolerance: tol >= 0.0;
  ensure
    same_uv: nearEqual(u,v,tol) implies
                (result >= 0.0);
    zero_case: (irange(u, 0.0, tol) and
                irange(v, 0.0, tol)) implies
                nearEqual(result, 0.0, tol);
```



500 elements per array, averaged over 100 runs

Related Work

- Ability to specify limits to overhead

  Dahlgren, T. L. "Performance-driven interface contract enforcement for scientific components". *In Proceedings of the 10th International Symposium on Component-Based Software Engineering (CBSE-07)*

- Selectively enforce assertions in software with a large user base

  Liblit, B., Aiken, A., Zheng, A. X., and Jordan, M. I. "Bug isolation via remote program sampling". *In Proceedings of the ACM SIGPLAN 2003 Conference on Programming Language Design and Implementation (PLDI '03)*

- Post processing log data to determine if an assertion was violated

  Sokolsky, O., Sammapun, U., Regehr, J., and Lee, I. "Runtime verification for wireless sensor network applications". *In Runtime Verification (2008), B. Finkbeiner, K. Havelund, G. Rosu, and O. Sokolsky, Eds., no. 07011 in Dagstuhl Seminar Proceedings*

Summary

- Contracts can present a significant performance overhead
- Offloading (postponing) the contract enforcement to improve performance is a reasonable approach
- Contracts whose computational complexity is significant are prime candidates
- Future Work: Try this approach on applications with significant contract overhead

Acknowledgements

- CCA Forum (http://www.cca-forum.org)
- Babel Team (http://computation.llnl.gov/casc/components/babel.html)

QUESTIONS?