The Xfork in the Road to Coordinated Sibling Transactions

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TM solving the wrong problem ?

- Finding parallelism is the key challenge of the multi-core era
- Transactional memory makes creating critical regions easier
- Transactional memory can also make..
  - finding parallelism easier
  - … but not with current model/API !

"Numerous types of processing are not well-served by [the flat transaction model's simplicity] " - Gray & Reuter

How will TM find threads ?

- Approach
  - Intratransaction parallelism
- Benefits
  - Improve performance of individual transactions & utilize cores
- Methodology
  - Revisit transaction model, API
- Advice
  - "Intratransaction parallelism requires genuine support for nested transactions." – Gray & Reuter

Nested Transactions

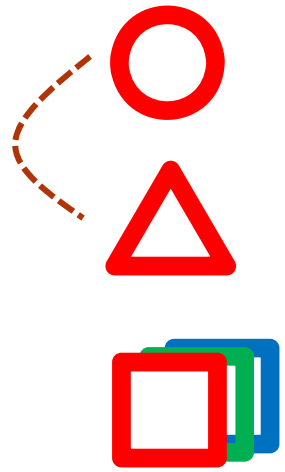
- Two types
  - Closed Nesting (commits into *parent)*
  - Open Nesting (commits into *world)*
- Serial closed nesting
  - Simpler semantics (than open)
  - Small or no performance gain
- Parallel closed nesting
  - Defined semantics for siblings
  - How much performance gain ?

```
Begin Tx (parent)
// work a
        Begin Tx (nested)
        // work b
        End Tx (nested)
End Tx (parent)
```

Forms of intra-transaction parallelism

- Independent
- Dependent
- Speculative

atomic Foo
{



}

atomic Foo
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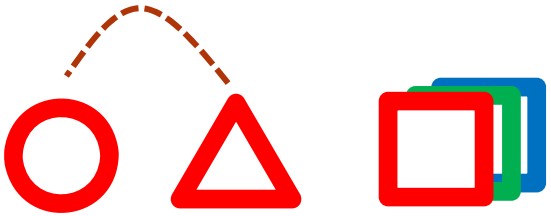
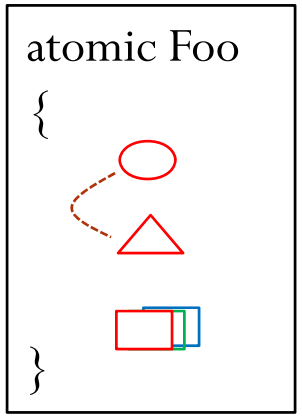
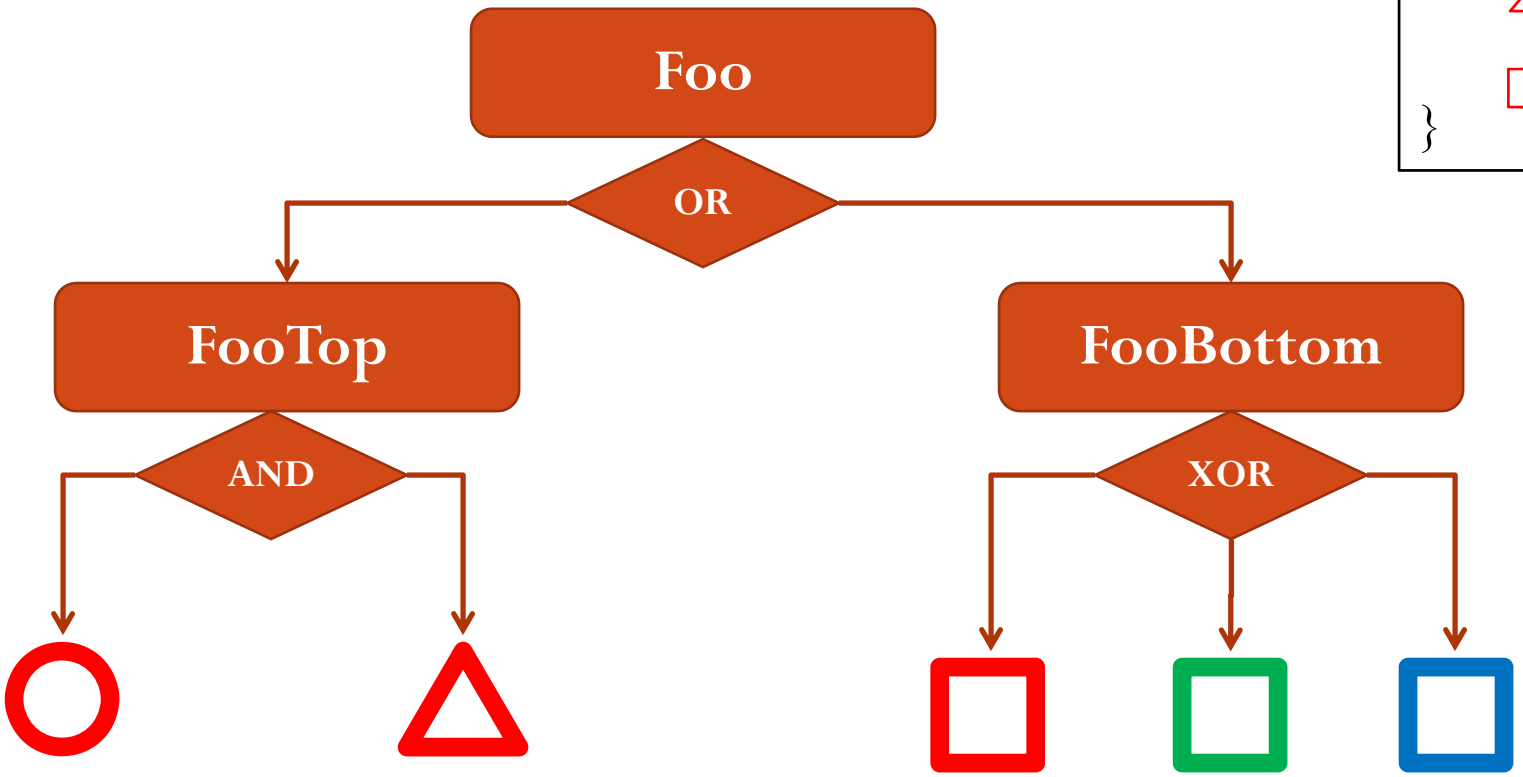


}

Programmer's mental picture





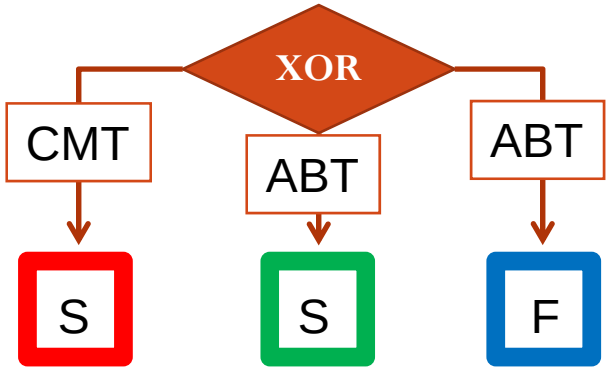
# of leafs = maximum amount of intratransaction parallelism

Coordination forms

- OR *(independent)*
  - Independent siblings
  - No short circuit
- AND *(dependent)*
  - All siblings must commit or none do
- XOR *(speculative)*
  - Exactly one is allowed to commit
  - Once one sibling commits, all others made to abort
- More forms conceivable

Coordinated Sibling Model

- Parallel closed nested transactions
  - Safety and semantics of closed nesting
- Coordination forms express multiple paradigms
  - fork/join
  - distributed transactions
  - speculative execution
- Sibling code returns Success/Fail
  - Commit/retry / abort decision made based on form, and status of siblings



xfork: API

- xfork API shields programmer from the dirty work
  - Threading, coordination, aborting, speculation, etc.

bool **xfork** (xforkForm, numForks,
xforkProc, optionalData);

enum **xforkForm** { AND, OR, XOR };
delegate xforkResult **xforkProc** (forkNum, optionalData);
enum **xforkResult** { Success, Failure };

xfork: Example

```
using (TransactionScope ts = new TransactionScope())
{
   sstm.txStore.write (myAddr, "hello");
   sstm.xfork( xforkForm.XOR,    // form
                  2,     // numForks
                   new Delegate (parallelSearchProc),  // xfProc
                  myList);    // data
   ts.Complete();
}

xforkResult parallelSearchProc(int forkNum, object myList)
{
    if (forkNum == 0)   { FwdTraverse(myList) } else { ReverseTraverse(myList) }
    return xforkResult.Success;
}
```

Sibling STM (SSTM): Architecture

- System.Transactions provides database-derived framework
- DB terminology:
  - TM: Transaction Manager (executes 2 phase commit protocol)
  - RM: Resource Manager (holds transactional data / votes in 2pc)
  - 'Enlisting': when RM first meets TM.
- **Sibling Executive (SibEx)** (RM)
  - Implements xfork semantics
- **TxStore** (RM)
  - Conventional STM

SSTM: SibEx

1. Schedule work for each fork on some thread

   Use existing thread-pool

2. Create sibling nested transactions
3. Invoking user-procedure for each fork
4. Enforce semantics of each sibling form

   May involve finding transaction outcome (OR-form), or enlisting and voting on outcome (AND/XOR-form)

5. Stalling the parent appropriately

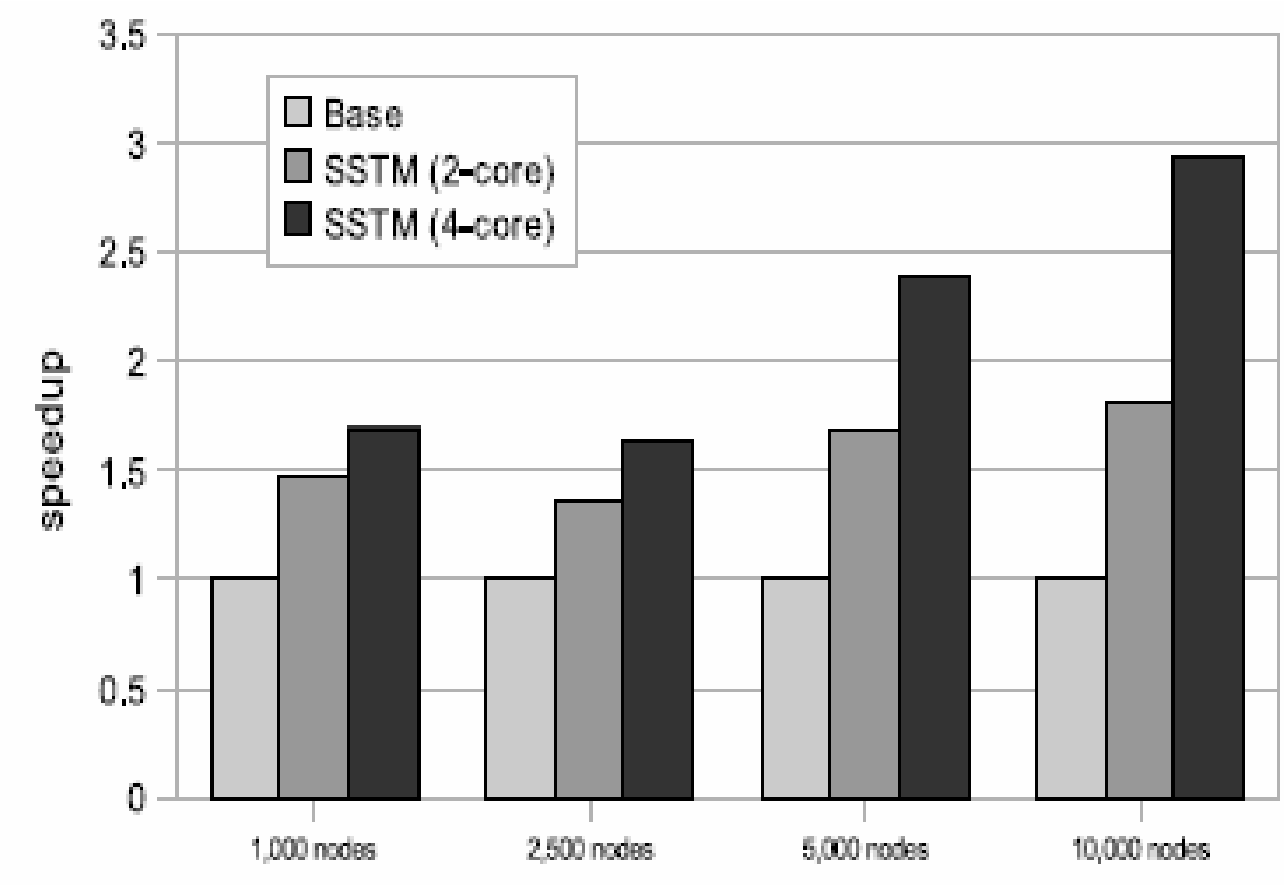
SSTM: TxStore

- Extends TL2 to support nesting
  - Key change: per-object version-number (for write set)
  - Additional synchronization to supported parallel access
- Extend System.Transactions to support nesting
  - Thread-local transactional context extended with "parents" list
- Low-level API, based on System.Object/ICloneable
  - object TxStore.Read(int address);
  - void TxStore.Write(int address, object obj);

SSTM: Prototype

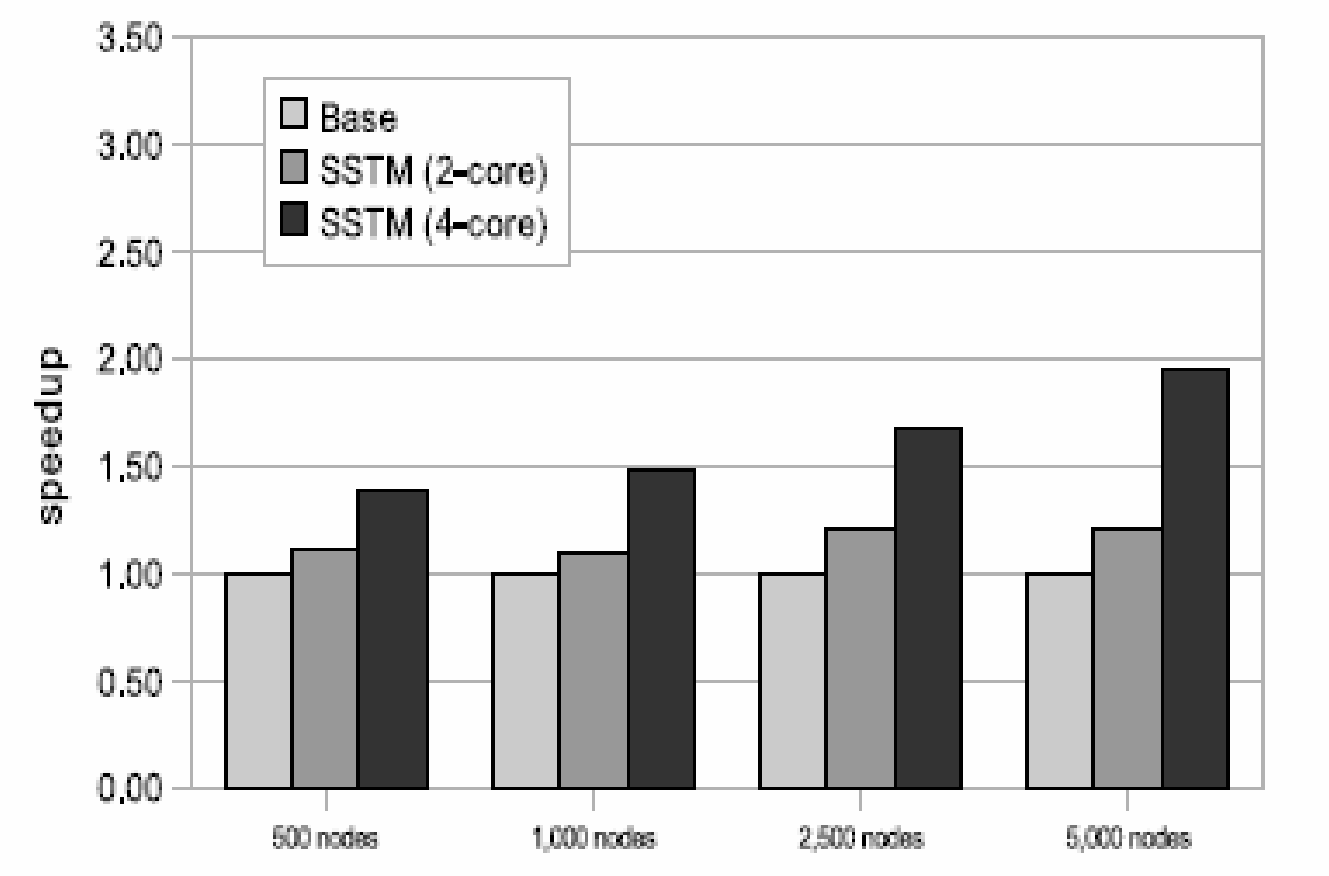
- System configuration
  - Intel Core2 Quad CPU running at 2.66 Ghz
  - Microsoft .NET v2 Framework, MS Windows Vista
  - SSTM: 2,345 lines of C# code
- Benchmarks (~600 loc)
  - SearchList:
    - Search linked list in parallel
  - Transfer
    - Debit/credit of bank accounts using two lists
- Compare SSTM to SSTM without xfork
  - Measure speedup, from 1 to 4 forks

SearchList benchmark



- Four-fork version also searches from middle of list

Transfer benchmark



- Higher overhead due to AND-form coordination

Related Work

- Nested Transactions
  - Formalized by [Moss81], [Beeri83]
  - Used in Argus[Liskov88], Camelot [Eppinger91]
- TM Nesting
  - HTM [Moravan06, McDonald06]
  - STM [Ni07, Harris07, Moss05]
- Parallelism
  - Fortress[Allen07], XCilk[Agrawal08]
  - Parallel for-loops, etc. in OpenTM[Baek07]
- Composition constructs (e.g. orElse) [Harris05]

Conclusion

- Intratransaction parallelism
  - Makes TM even more relevant to the challenges of multi-core
- Coordinated siblings
  - Transaction model that suits this type of processing
- xfork
  - Makes coordinated siblings easy to use

Will intratransaction parallelism become a commodity ?